DOCUMENT RESUME

ED 409 218 SE 060 485

AUTHOR	Blakeslee, Theron; Kahan, Janet
TITLE	Michigan Curriculum Framework: Science Education Guidebook.
INSTITUTION	Michigan State Dept. of Education, Lansing.
PUB DATE	96
NOTE	115p.
PUB TYPE	Guides - Non-Classroom (055)
EDRS PRICE	MF01/PC05 Plus Postage.
DESCRIPTORS	*Curriculum Design; Educational Resources; Educational Strategies; Elementary Secondary Education; Evaluation; *Professional Development; *Science Curriculum; Science Education; *Scientific Literacy; State Curriculum Guides
IDENTIFIERS	*Michigan

ABSTRACT

This Guidebook contains ideas, examples, suggestions, and resources that can help teachers create and implement a science curriculum for all students. It is designed to be used as a guide for exploring the issues of vision, teaching, curriculum, and assessment that should be considered and debated in the move towards scientific literacy. Chapters include: (1) "Science Literacy"; (2) "Planning a Strong Science Program"; (3) "Designing the Curriculum"; (4) "Teaching for Science Literacy"; (5) "Classroom Assessment"; (6) "Professional Learning"; and (7) "Resources". (JRH)

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Michigan Curriculum Framework

SCIENCE EDUCATION GUIDEBOOK

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Guiding Principles for Curriculum and Teaching

1. Science is for all students.
2. Students' understanding of science must be constructed by the [illegible]
3. Students' ability to use scientific knowledge requires a deep understanding.
4. Understanding is strengthened when connections between ideas are uncovered.
5. Activities used in teaching should promote active learning.
6. Curriculum and teaching should elicit, value, and address students' ideas.

Why we created a Science Education Guidebook

Several years ago, just after *Michigan Essential Goals and Objectives for Science Education* was released, we began to receive comments from people around the state. They were enthusiastic about the idea of science literacy, and the objectives made sense to them, but they were not sure how to put the objectives together into a K-12 curriculum. They agreed that more students needed to do more science, but they had questions like "Should we teach physical science in 7th grade, should we teach life science in 8th grade, should we try to integrate our science courses?"

This Guidebook is a response to those questions. On the following pages are ideas, examples, suggestions and resources that can help you create and implement a science curriculum *for all students*. You can use this book as a guide for exploring the issues of vision, teaching, curriculum, and assessment that should be thought about and debated as you move toward higher levels of science literacy.

We have been very fortunate to receive the guidance of many dedicated science teachers, school administrators, university science educators, and others in preparing this guidebook. They provided us with thoughtful and insightful direction and substantive comment and critique on its various drafts. They continuously held us to their first and foremost demand that this book be *useful*, and therefore, by definition, as short as possible.

The Guidebook is designed to be used as a tool, with pages throughout where you can keep notes, compile your own ideas, and create your own plans. It was never intended to be read from cover to cover, but to be used as your needs demanded, for help in bringing new ideas to your community, or creating a new curriculum, or working together to move your teaching away from lecture and textbook reading.

We hope it lives up to its billing as a companion to the *Michigan Essential Goals and Objectives for Science Education*. We also hope it helps you help your district teach more children more science more often!

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Michigan Dept. of Education

and

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SCIENCE EDUCATION GUIDEBOOK

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This Guidebook is a companion to the *Michigan Curriculum Framework*. The *Framework* contains standards and benchmarks for science, mathematics, English language arts, and social studies, along with guidance on school improvement planning, authentic teaching, classroom assessment, and professional development. The Guidebook provides additional detail, resources and tools specific to science education.

Comments are welcome on any aspect of this document. Call or write Dr. Theron Blakeslee, Michigan Department of Education, P.O. Box 30008, Lansing, MI 48909; (517) 373-0454; BLAKESL6@pilot.msu.edu

If you would like to receive periodic updates of this document and its appendices, send a postcard with your name and address to "Science Guidebook Updates" c/o Theron Blakeslee at the above address.

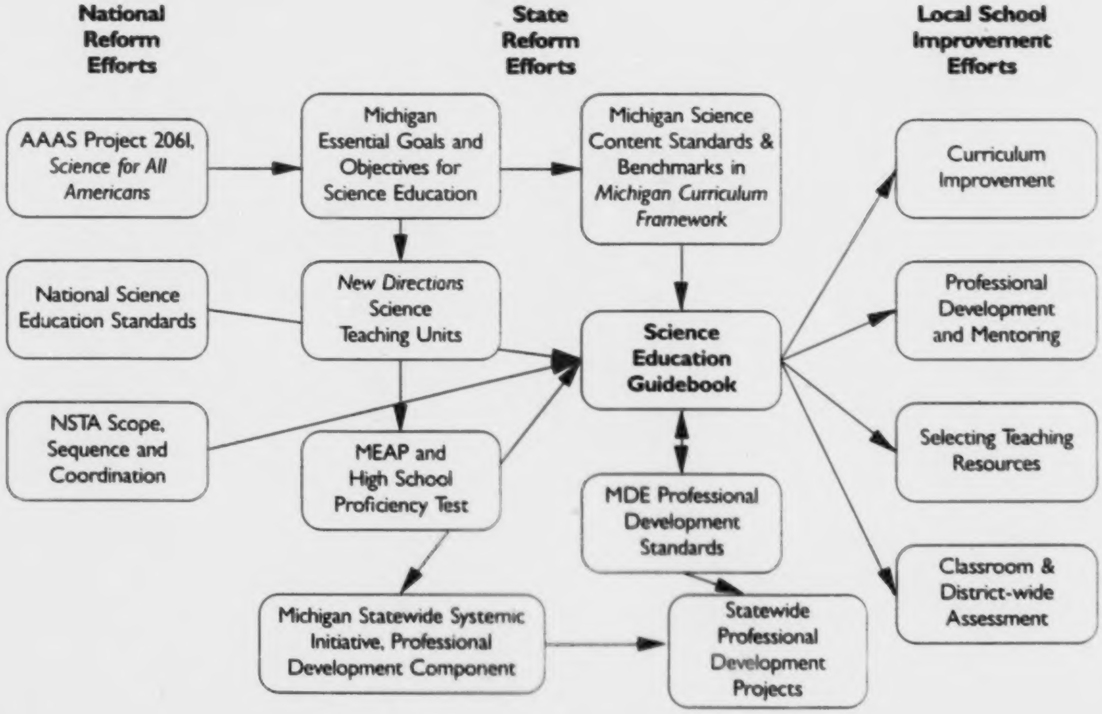
This work was funded in part by the U.S. Department of Education, National Eisenhower Program.

The quote from Carl Sagan on page 1 appeared in an interview by Anne Kalosh in the October 1994 issue of *Hemispheres*, United Airlines' in-flight magazine.

The quote from Herriet Tyson on page 57 is from her book *Who Will Teach the Children*, published in 1994 by Jossey-Bass.

See the MDE Curriculum Development Program home page, at http://cdp.mde.state.mi.us, for electronic versions of many items contained in and related to this Guidebook.

Where this Guidebook Fits with Other Science Improvement Efforts


National Reform Efforts
State Reform Efforts
Local School Improvement Efforts
AAAS Project 2061, Science for All Americans
Michigan Essential Goals and Objectives for Science Education
Michigan Science Content Standards & Benchmarks in Michigan Curriculum Framework
Curriculum Improvement
National Science Education Standards
New Directions Science Teaching Units
Science Education Guidebook
Professional Development and Mentoring
NSTA Scope, Sequence and Coordination
MEAP and High School Proficiency Test
Selecting Teaching Resources
MDE Professional Development Standards
Classroom & District-wide Assessment
Michigan Statewide Systemic Initiative, Professional Development Component
Statewide Professional Development Projects

SECTION 1

SCIENCE LITERACY

A Vision for Science Education

Science is a way of making sense of the natural world. Scientists seek to describe its complexity, to explain its systems and events, and to find the patterns that allow for predictions. Science is the basis for the design of technologies that solve real-world problems.

Not all students will become scientists or engineers. But science and technology occupy ever-expanding places in our everyday lives. As citizens, we are asked to make decisions about social issues that involve science and technology. As workers, we have occupations that increasingly involve science and technology. In the 21st century, adults will need to be comfortable and competent in a complex scientific and technological world.

Schools have the responsibility of preparing students for the future. Schools must prepare all students—regardless of their future aspirations—to be scientifically literate. Therefore, all graduates of our schools should be

- knowledgeable about the important concepts and theories of the three major branches of scientific study: earth, life, and physical sciences;
- able to think scientifically and use scientific knowledge to make decisions about real-world problems;
- able to construct new knowledge for themselves through research, reading, and discussion;
- familiar with the natural world, and respectful of its unity, diversity, and fragility;
- able to make informed judgments on statements and debates claiming to have a scientific basis;
- able to reflect in an informed way on the role of science in human affairs.

> *"There's hardly an aspect of modern society that doesn't depend on intelligent decision-making in science and technology. Yet we have arranged things so that almost no one understands it. That's a clear prescription for disaster."*
>
> Carl Sagan

This kind of literacy in science does not come easily.

The science teaching of the past, with its pattern of monotonous lecturing, note-taking, and scattered lab experiences, will not help students build a deep, coherent understanding.

Teaching students to become literate in science is more about asking them questions and helping them find answers than telling them everything they need to know.

What would it look like to teach science this way? Imagine a classroom where students are excited about science, not fearing its complexity. A classroom where teachers pose challenging and developmentally appropriate problems for students, help them set up relevant investigations and encourage them to think about what the results of these investigations mean. Where teachers explain science concepts to students, but only in the context of investigations, when explanations are most meaningful. In this classroom, teachers often say "What would happen if...?", "How can we find out?", "Why do you think this happens?", and "Why do you believe that?"

Students do much of the talking in this classroom. They ask questions. They collaborate with each other when setting up and conducting investigations. They make predictions. They discuss what certain results mean. They articulate their own ideas about how things work and why things happen. These classrooms are intellectually stimulating and active places. Students are constructing ideas about how the world works.

The National Science Education Standards and *Science for All Americans* describe similar visions. See the resource sections for information on how to obtain these documents.

A curriculum for literacy in science helps students make sense of the world around them. It helps students apply their knowledge of science to everyday phenomena, systems and events. It respects and values the growth of students' understanding and does everything possible to nurture it.

What can you do?

As a faculty, create your own vision of a student who is prepared well for the 21st century, and of a classroom that promotes literacy in science. Use this vision statement as a model. Include parents, administrators, and school board members in its creation. Share your vision with teachers in other subject areas.

These lines and similar spaces throughout the book are for your own notes.

Moving toward the vision

To make this vision a reality, schools need to become places where each student's growth and learning is highly valued by the entire community, and the craft of teaching is equally respected and nurtured. Parents, students, teachers, and administrators all understand their opportunities and responsibilities for making this vision a reality.

> *Parents, other community members, administrators, students and teachers all need to work together toward this vision of scientific literacy.*

Parents can become partners:

- by supporting their daughters and sons as they learn, encouraging them to participate fully in school and helping with homework and projects when possible.
- by viewing themselves as partners with their daughter's and son's teachers.
- by supporting time and resources for teachers' work with colleagues and professional growth.
- by understanding the new ways of teaching science described in this Guidebook.
- by becoming mentors from their place of business, or finding other volunteer activities which will assist schools.
- by participating with their daughters and sons in community science activities, including science museums, 4H activities, Family Science programs, and other appropriate events.

Students should take an active role in promoting their own learning:

- by taking responsibility for their own learning.
- by developing goals for themselves, and asking for help when needed.
- by encouraging the whole system to do its best for them.

Teachers work together as professional colleagues:

- by discussing problems and opportunities within and across subject areas, and with school administrators.
- by making fullest use of individual and collective planning time.
- by continuously assessing their own teaching, and their teaching materials.
- by being fully committed to their own professional growth and their school's organizational development.

Administrators encourage and support the improvement of practice:

- by leading the development of the school's philosophy of teaching and learning, and insisting on its use when considering new curricula and instructional practices.
- by giving teachers some measure of control over critical aspects of instruction, including grouping of students and scheduling of instructional time.
- by providing opportunities for innovation at all levels, and supporting new practices (even when these practices create classrooms very different from the traditional).
- by providing resources for hands-on activities, including equipment and materials with storage and distribution capabilities; and appropriate educational technology.
- by providing safe and well-designed science classrooms, including flat work surfaces, access to water, adequate electrical outlets, and adequate ventilation.
- by keeping the student/teacher ratio at reasonable levels for laboratory work, where safety is paramount. This can be accomplished by reducing class size, or providing additional adult help in larger classes.
- by making professional development a priority: maintaining an ongoing school-wide professional development plan with a focus on collaborative, job-embedded strategies, creating time for collaboration as an integral part of teachers' work day, and by informing and convincing the public of the critical need for professional development.
- by making a commitment to placing only well-qualified teachers, who are committed to teaching science, in these crucial positions where children's futures are being shaped.

Making this your own

What conditions are needed to make your vision a reality? What can teachers, students, parents, administrators and others do to achieve these conditions? Add detail to the above statements to make them concrete for your own district.

Content Standards and Benchmarks

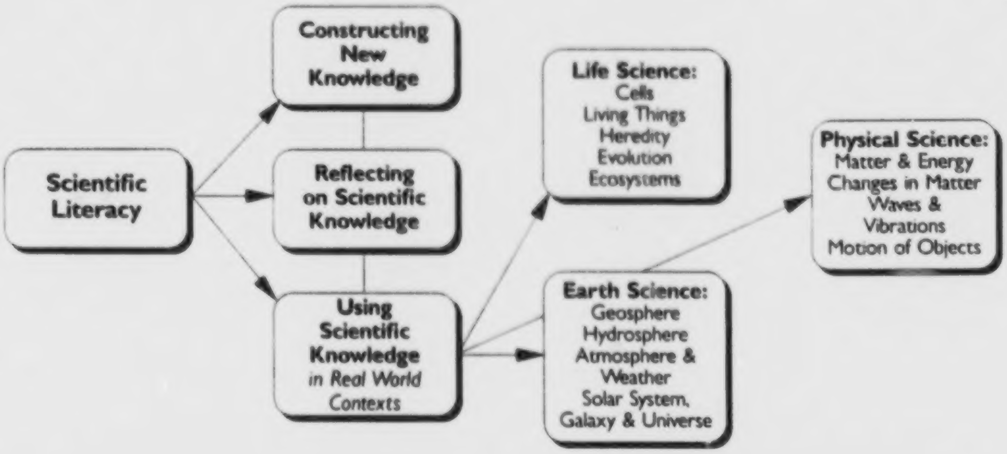
Michigan Goals for Science Education

- *Emphasize understanding over content coverage*
- *Emphasize learning that is useful and relevant outside of school*
- *Promote scientific literacy for all students*
- *Promote interdisciplinary learning*

The *Michigan Science Education Content Standards and Benchmarks*, also known as the *Michigan Essential Goals and Objectives for Science Education—MEGOSE* (see box below) are standards for science education content and performance that can take Michigan science classrooms into the next century. Based on the Goals listed in the margin, they relate directly to the vision of literacy in science (pp. 1-2).

The *Content Standards and Benchmarks* describe what all students should be able to do by the end of 4th, 7th and 12th grades. They include such tasks as "Describe how all organisms in an ecosystem acquire energy directly or indirectly from sunlight" and "Design and conduct simple investigations."

The Standards and Benchmarks are listed by three major activities of science literacy: ***using scientific knowledge, constructing new knowledge, and reflecting on scientific knowledge***. The "ecosystem" benchmark above is an example of using scientific knowledge—in this case, using knowledge about photosynthesis, food chains, and the relationship between food and energy—to understand and appreciate how organisms are connected to each other by their need for energy. ***Using scientific knowledge benchmarks*** generally ask students to describe, explain, predict and design systems and phenomena of the real world.


Scientific Literacy
Constructing New Knowledge
Reflecting on Scientific Knowledge
Using Scientific Knowledge in Real World Contexts
Life Science:
Cells
Living Things
Heredity
Evolution
Ecosystems
Earth Science:
Geosphere
Hydrosphere
Atmosphere & Weather
Solar System, Galaxy & Universe
Physical Science:
Matter & Energy
Changes in Matter
Waves & Vibrations
Motion of Objects

From *Goals and Objectives* to *Content Standards and Benchmarks*— Only the name has changed!

The *Michigan Essential Goals and Objectives for Science Education*—MEGOSE—has a new name and a new look, but only to be consistent with other subject areas. The objectives have not changed from the 1991 "red and blue" version. Each objective corresponds to a benchmark, under the same headings of "using," "constructing," and "reflecting." The name change reflects a shift on the national and state level to refer to learning objectives as "content standards," with "benchmarks" to judge students' progress at the end of a cluster of grades. The 1991 document is still a valuable resource for curriculum committees and individual teachers.

The "investigations" benchmark on the previous page refers to a skill needed for *constructing new knowledge*. Other *constructing scientific knowledge* benchmarks include posing questions, using technology and sources of information, drawing conclusions and solving problems, and communicating findings.

The *reflecting on scientific knowledge* benchmarks ask students to justify scientific claims based on evidence and reason, discover thematic connections between areas of science, recognize that science is only one way of understanding the world, and understand the role that people of all cultures have played in science.

Originally developed from the AAAS Project 2061 report *Science for All Americans*, the benchmarks are the basis for the *New Directions* Science Teaching Units, as well as the new MEAP and high school proficiency tests. Project 2061 has since developed its own *Benchmarks for Science Literacy*, which are very similar to Michigan's Science Education Content Standards and Benchmarks, but written in narrative form. Project 2061's *Benchmarks* are an excellent companion to MEGOSE, and often helpful for deeper understanding of the important ideas behind Michigan's benchmarks.

Integrating the Benchmarks

For the sake of clarity, the *using* benchmarks are divided into three sections: using life science, using physical science, and using earth science. The writers were not suggesting that the K-12 science curriculum should necessarily be organized along these same lines.

Instead, the benchmarks should be intertwined in instruction, in two major ways. First, following the goal of promoting interdisciplinary learning, the *using* benchmarks in life, physical and earth science can

An example from MEGOSE: Using Knowledge of Life Science (Organization of Living Things)

Objectives—Middle School	Related concepts, terms, and tools	Real-world contexts
6) Compare and classify organisms into major groups on the basis of their structure.	Characteristics used for classification: *vertebrates/invertebrates, cold-blooded, single-cell/multicellular, flowering/non-flowering*	Representation organisms, such as *dog, worm, snake, Amoeba, geranium, wheat*
7) Describe the life cycle of a flowering plant.	Flowering plant parts and processes: See objective 5 above, plus *embryo, pollen, ovary, egg cell, germination, fertilization*	Common flowering plants, such as *bean, tulip*
8) Describe evidence that plants make and store food.	Process and products of food production: *photosynthesis, starch, sugar, oxygen*	Plant food storage organs, such as *potato, onion* Starch storage in plants grown under different conditions Also see Cells objective 9
9) Explain how selected systems and processes work together in animals and plants	Systems/Processes: *digestion, circulation, respiration, endocrine, reproduction, skeletal, muscular, nervous, excretion, transport, growth,*	Interrelations of body systems during selected activities, such as *among skeletal, muscular, circulatory, and respiratory systems during physical exercise*

be intertwined in many interesting topics, including weather and storms, growing plants, body systems and functions, space exploration, waste disposal, manufacturing new materials, health care, and so on.

Second, the constructing and reflecting benchmarks need to be mastered at the same time and in the same real-world contexts in which students are learning how to use scientific knowledge. That is, students do investigations that pose important questions related to the *using* benchmarks (e.g., How do humans use food for energy and growth? How do clouds form? How are simple electrical devices constructed?) While exploring these questions, students learn to design and conduct investigations, collect data and make observations, pose additional questions, and justify their hypotheses based on evidence and reason. They then use the knowledge they have constructed about the question to reflect more deeply about the topic.

> *he constructing and reflecting benchmarks should not be mastered in isolation from the using benchmarks, but should be woven together in instruction.*

Standards of performance

Constructing, using and reflecting on scientific knowledge are the essential *performances* of scientifically literate people—the activities they engage in that make use of scientific knowledge in real world settings. The benchmarks are actually statements of these performances (e.g., "*Explain* how selected systems and processes work together in animals and plants.") The degree to which students accomplish a benchmark can be judged by how well they incorporate the concepts, terms and tools listed in the second column of the tables, as well as by how they place their performances in real-world contexts, such as those found in the third column of the tables. Guidance for judging students' performance can also be found in the essays throughout MEGOSE, which describe what successful performance of the benchmarks would involve.

How Content Standards and Benchmarks are related to MEGOSE

In the spring of 1995 the Goals and Objectives, which had been in use for four years, were reformatted into Content Standards and Benchmarks. Each benchmark became an objective, as shown in the graphic on p. 8. However, not all of the information in MEGOSE was translated into the new document: the essays are only available in MEGOSE.

As part of the larger review and development of state content standards and benchmarks, the science standards and benchmarks were opened for public comment and possible revision. Very little was changed as a result of this review: None of the benchmarks were changed, and only one of three "central questions" concerning evolution was reworded, from "How do scientists trace the origin and development of species?" to "How do scientists construct and

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scientifically test theories concerning the origin of life and evolution of species?"

MEGOSE	➡	**Content Standards and Benchmarks** (Reformatted MEGOSE)
Introduction containing the Goals	➡	Vision statement
Topic headings		
Central Questions used to organize the Objectives	➡	Content Standards
Essays on each Central Question		
Objectives: Activity, key concepts, & real-world contexts	➡	Benchmarks: Activity, key concepts, & real-world contexts

Over the next few years both MEGOSE and *Michigan Content Standards and Benchmarks* will be available for curriculum work. MEGOSE should continue to be used by curriculum committees because of the additional information it provides. However, the *Michigan Curriculum Framework* (which contains the Content Standards and Benchmarks) has additional support material on planning, assessment, and professional development.

Revising the Standards and Benchmarks

Revision of the standards and benchmarks will not happen often or capriciously, because schools put considerable time into creating curricula based on the benchmarks. But the document should be viewed as dynamic and open to review and revision in the light of significant new knowledge and experience.

National Science Education Standards

Science education standards were released in December, 1995 by the National Research Council of the National Academy of Science. These standards include sections on content, teaching, assessment, professional development, science programs, and the larger system in which science teaching operates. The Content Standards are very similar to *Science for All Americans* and *Benchmarks for Science Literacy*, and therefore are highly compatible with MEGOSE. Written in narrative form, they may also give additional insight into Michigan's benchmarks. Other sections of this national document have been drawn on to develop corresponding sections in this Guidebook. Ordering information is available in the resources section.

The *Michigan Essential Goals and Objectives for Science Education* is a primary tool for district curriculum development. Essays throughout the book discuss students' common learning difficulties, and describe what successful performance of the objectives/benchmarks would involve.

The *Michigan Content Standards and Benchmarks* are available as part of the larger document *Michigan Curriculum Framework*. See the resource section for ordering information.

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SECTION 2

PLANNING A STRONG SCIENCE PROGRAM

Improving curriculum, teaching, learning, and school structure is ultimately the responsibility of the entire education community—teachers, administrators, parents, school board members, students, and other community members. However, you may begin to make changes with only a small curriculum committee, perhaps a subcommittee of your school improvement team. The key is to find ways to expand the committee's work to include *all* stakeholders at an early stage. What follows is a practical guide to the process of developing a strong science program.

> *Curriculum planning must be an integral part of the continuous school improvement process.*

Consider your commitments

1. Help teachers become familiar with the *Science Content Standards and Benchmarks/Michigan Essential Goals and Objectives for Science Education*. Carefully consider the Goals (listed on p. 5) and Vision (pp. 1-2) and what they mean to teachers in your district. Use these as a guide to write your own vision statement, to clarify what you want *your* graduates to know and be able to do. Study and talk about the *Benchmarks/Objectives* to understand what they require of students. You may wish to do this by grade clusters (elementary, middle, high school).

Districts that haven't spent time up front deliberating on and debating the issues raised by the Goals and the Benchmarks/Objectives and the vision statement seem to get continually sidetracked by philosophical debates as the planning process continues. Writing your own vision statement is an excellent way to document your shared commitments for science education. If your district has a broad mission statement, study it and reflect on how the general goals of your district might be carried forward and made specific in your science program.

2. Consider how well students are learning what you want them to learn right now. Use data from assessments that are tied directly to the objectives, standards, and benchmarks that you want students to learn.

MEAP data does not provide much of this kind of in-depth assessment information about students, although the area-specific component of the MEAP will (to be given beginning in 1996-97). You need to develop and use good classroom assessments to tell you about students' learning on each objective, standard, or benchmark. See the section on classroom assessment, pp. 57-60.

Plan and communicate

ake presentations to the school board often. They will eventually have to approve your curriculum plans.

3. Develop a draft for your district's scope and sequence, or K-12 curriculum framework. The section on K-12 curriculum frameworks, pp. 15-38, has samples and ideas. You might do this in small working groups, each responsible for one grade cluster. Decide where each of the state science benchmarks/objectives belongs in the district scope and sequence, and the extent to which they are adequately and appropriately addressed.

The process of creating a scope and sequence—of deciding what to teach at each grade level—is a process of negotiating between what individual teachers would *like* to teach, what the district as a whole feels is *important* to teach, and what materials are *available* on particular topics. The process begins at this step, but the scope and sequence will continue to be refined as teaching materials are tried out and teachers become experienced in teaching the new curriculum.

4. Get initial buy-in to an early version of the proposed curriculum framework from other teachers, administrators, and the school board. Introduce the plan early in the process to related school groups like the parent council and the district school improvement team.

Ask for input at all stages in the process. The more the entire community is involved in planning, the less chance that they will be surprised later. There will be fewer objections, if everyone involved can feel it is somehow *their* plan. Seriously consider having an interested community member on your curriculum committee from the start. They will be an asset when it comes to introducing and explaining your proposed changes to parents and the school board.

Many curriculum committees have difficulty gaining cooperation from teachers who were not involved in the early stages of development. Teachers can be unwilling to use the new plan if they were not asked for input. Ask for and be open to feedback, and be prepared to revise the curriculum to reflect suggestions. Responding to thoughtful suggestions builds ownership.

You don't have to write your own teaching materials to be the author of your classroom curriculum. You are its author when you select appropriate activities, reading passages and video, writing tasks, etc., and blend them into a coherent instructional unit.

Find instructional materials and develop new units

5. Begin by creating one new, coherent, sequenced unit of study per grade level, developed from your scope and sequence. Refer to the section on unit planning, pp. 35-38. This one new unit will allow

CURRICULUM REFORM AT VICKSBURG SCHOOLS

A Shared Vision For The Classroom

The Vicksburg Water Partners Program began in Vicksburg Schools as a way to improve student interest and achievement in grades 1-7 by improving curriculum, materials, and methods. Before any changes were made in the curriculum, a cadre of teachers representing all grade levels reviewed constructivist principles, *Science For All Americans*, and the current textbook-driven curriculum. Then the cadre developed a vision for what elementary science education should look like in the future. The vision statement, submitted to all teachers for review and approval and used as a guide for all changes, has four parts:

I. ***INTEGRATION OF SUBJECT AREAS:*** Less is more. Don't be pushed by the clock to cover too much. Teach whole units or themes. Use water as a connecting idea.

II. ***DISCOVERY LEARNING:*** The teacher is a facilitator and leader. Learning should be hands-on/minds-on. Real life experiences or contexts are central to learning. Students must have opportunities for involvement and success in learning.

III. ***ASSESSMENT (PRE/POST):*** Alternative assessment techniques (portfolios, interviews, essays, etc.) should be used. Student outcomes and goals should be clearly stated. Use strategies for eliciting students' prior knowledge.

IV. ***SUPPORT:*** Flexible training, material, release time and other staff support are critical to success.

Advisory Committee Provides Input

In order to be sure that there was support for changes in science education from the community, the Vicksburg Water Partners Program formed an Advisory Committee made up of teachers, parents, students, administrators, business people, educators from Western Michigan University, and local government officials. The committee meets once every two months and receives progress reports on the changes being made and then makes recommendations for further changes. Issues regarding changes are thoroughly discussed and potential obstacles are identified and dealt with. The Advisory Committee has met for almost three years and has helped greatly in moving the program forward.

Teachers as Authors/Developers

The teachers are the authors of the elementary science curriculum. One or two teachers at each grade level work with the state objectives and a large library of activities to develop units based on the objectives. These activities are computer formatted, and given back for a first phase of field testing. The teacher makes modifications and then the other teachers at that grade level are in-serviced on how to teach the unit and are asked to field test them again. The suggested modifications are then incorporated into the final version, and all teachers are given credit as developers.

In-House Staff Development

The Vicksburg Water Partners Program is responsible for elementary staff development in science. The approach of program staff is to do all development in the district. All teachers at a grade level are released for a day twice each year to do hands-on activities that they will teach in their units or help with development of authentic assessment techniques. The program staff facilitate the trainings and attempt to model constructivist, hands-on approaches in an atmosphere of fun.

Trouble-Shooting

Feedback is collected regarding the changes being made through "trouble-shooting meetings." In these meetings, often held during science in-services, teachers can identify problems with curriculum, assessment, or materials that are keeping them from being more effective. Program staff listen to and note these concerns and get back to the teachers on progress that is being made to resolve or minimize the problems.

See the resource section for lists of new instructional materials that you might want to examine.

teachers to try out new teaching materials and methods, and gradually adjust their science curriculum to match the new district K-12 curriculum framework.

Creating units is something that all teachers do, regardless of whether they are using a textbook, a commercially prepared unit, or their own written materials. Teacher's units consist not only of textual reading material, but also all the overhead transparencies or lecture notes, experiments and other hands-on activities, reading and writing assignments, assessments, etc. Many schools or districts allow the entire teaching staff at one grade level to construct units together. In this way, all the teachers become the "authors" of their curricula.

Look for available teaching materials which fit your first unit and other units in your proposed scope and sequence. These materials must adequately and appropriately address the relevant objectives at the grade level. If these materials are complete in themselves, they may become the actual units. If not, they may be the foundation which you use to develop new units. If necessary, revise the district curriculum framework to reflect your selection of teaching materials.

The new teaching materials you find become the basis for your new classroom curricula. But beware: Not all materials that look good at first are appropriate to either your district's needs or the state science benchmarks/objectives. When you find materials you like, you still may have to take out of them what doesn't fit in your unit, and perhaps blend portions of several good units or textbook chapters together to make a curriculum that really works for you.

If you develop your own units from scratch, get a commitment from the district to support long-term curriculum development, pilot testing throughout the school year, and in-services on the new units.

ou don't have to write your own teaching materials to be the author of your classroom curriculum. You are its author when you select appropriate activities, reading passages and vides, writing tasks, etc. and blend them into a coherent instructional unit.

6. Find or create appropriate assessments for all new units. This helps evaluate how effective the new units are.

If you select a textbook, choose the portions which will complement each unit. Most often you will need to find supplemental materials to complete the unit, including hands-on activities, videos, etc.

7. Take time to consider how well different groups of students are learning science. Find out if girls and minority students are falling behind or being left out. MEAP and High School Proficiency Test results can tell you this. Plan strategies to correct these problems. See the section on Supporting and Encouraging All Students, pp. 54-56.

Develop and implement a 5-year plan

8. Begin to develop a 5-year plan that will include testing new teaching materials, purchasing and storing necessary equipment and supplies, providing teachers with appropriate professional development and support, and evaluating the program as it develops. This plan should include timelines, funding sources, and

commitments from all parties.

You will refer to this plan many times as your implementation proceeds. Be prepared to modify it to reflect what you learn as you make progress. Get support from administrators, and approval from the school board.

The plan is a set of agreements for what all teachers and administrators will do to improve science teaching and learning. It is a result of negotiation and compromise between everyone involved with science education.

f your district works in separate elementary, middle, and high school teams, make sure that a steering committee or science coordinator keeps track of the work of each group, looking for possible connections or conflicts.

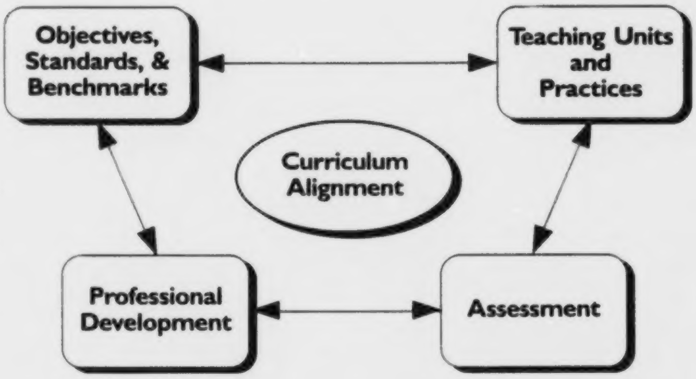
9. Pilot all new units before adopting them for your district.

Piloting units provides a baseline of information about materials needed, techniques for classroom management, connections to other curriculum areas at that grade level, and professional development needs. It also creates a pool of local experts to help with in-service training on those units.

Piloting is a good way to get started teaching new topics with new materials. Changes do not have to be made too abruptly, and what teachers learn in piloting one new unit can be used to help implement additional units. If all of the teachers at one grade level try a new unit together, they have a basis for discussion about how their science improvement efforts are going.

10. Consider interdisciplinary connections and find ways to infuse them into your units.

Interdisciplinary connections include reading (gaining new knowledge from informational passages, periodicals, and books), writing (describing, explaining, conveying designs), mathematics (being quantitative whenever appropriate), social studies (making connections between geography, earth science and ecology, or between social issues and the science behind them) and art (drawing and painting, singing, dancing, and acting as ways to convey scientific understandings). Many science units do not include opportunities for these interdisciplinary activities.


Objectives, Standards, & Benchmarks
Teaching Units and Practices
Curriculum Alignment
Professional Development
Assessment

Adapted from Macomb County science curriculum development materials.

11. Consider what has been learned through piloting units, and develop a complete in-service plan (see the section on professional learning, pp. 61-77). Coordinate the science professional development plan with the overall school improvement plan.

Teachers need professional development opportunities when they change their curriculum. New materials, new content, new expectations about students' and teachers' roles require that teachers have time to learn and to reflect on their teaching.

Support teachers and evaluate successes and failures

12. Support new units for a year; collect feedback.

Support includes buying materials and consumables, setting up "user-groups" for each grade level where teachers can share information about the new teaching they're doing. It also includes establishing some form of support for teacher questions, and evaluating the unit. Find out if the units are teachable, likable, and—especially—*effective* in helping students meet the objectives.

Support also includes helping teachers change the way they teach if necessary. Peer coaching or demonstration teaching are key ways to help teachers learn how to teach in new ways. See the section on professional development, pp. 61-77, for additional suggestions.

13. Continue to add new units as teachers become comfortable with new ways of teaching. Adjust the curriculum framework (the scope and sequence) as necessary. Adjust the professional development plan as necessary.

A five-year plan for improving science teaching and learning

Year 1	Year 2	Year 3	Year 4	Year 5
Become familiar with the *Michigan Essential Goals and Objectives for Science Education.* (The Content Standards & Benchmarks) **Funding source:** Eisenhower **Resource:** Math/Science Centers	Look for teaching materials that teach to the appropriate objectives. **Resource:** Math/Science Centers	Buy, distribute and re-stock equipment for 1st-year units.	Buy, distribute and re-stock equipment for 2nd-year units.	Inservice all teachers on new units and begin teaching them. **Funding:** Eisenhower
Develop a draft K-12 scope and sequence (district curriculum framework)	Use new materials to develop unit plans for at least one unit per grade ("1st-year units").	Inservice all teachers on 1st-year units and begin teaching them. **Funding:** Eisenhower	Inservice all teachers on 2nd-year units and begin teaching them. **Funding:** Eisenhower	Support all units, collect feedback. Revise as needed.
Place Objectives/ Content Standards and Benchmarks in scope and sequence.	Have some teachers pilot 1st-year units before adopting for whole district.	Support units, design and use assessments.	Support units, design and use assessments.	
Share district curriculum framework with "stakeholders" and get feedback. Present to the Board. Talk to the PTA/PTO. Put articles in school newsletters. Then revise curriculum framework as needed.	Infuse interdisciplinary materials and activities into 1st-year units. Have field-test teachers work cooperatively to develop equipment lists for units.	Begin to develop unit plans for 2nd-year units within each grade; acquire new instructional resources as needed for the new units. **Funding:** Eisenhower **Resource:** Math/Science Centers	Begin to develop unit plans for 3rd-year units within each grade; acquire new instructional resources as needed for the new units. **Funding:** Eisenhower **Resource:** Math/Science Centers	
Develop a 5-year plan for unit planning, purchasing equipment, in-service, support, & evaluation.	Edit and distribute 1st-year units to all teachers.	Pilot 2nd-year units before adopting them.	Pilot 3rd-year units before adopting them.	

SECTION 3

DESIGNING THE CURRICULUM

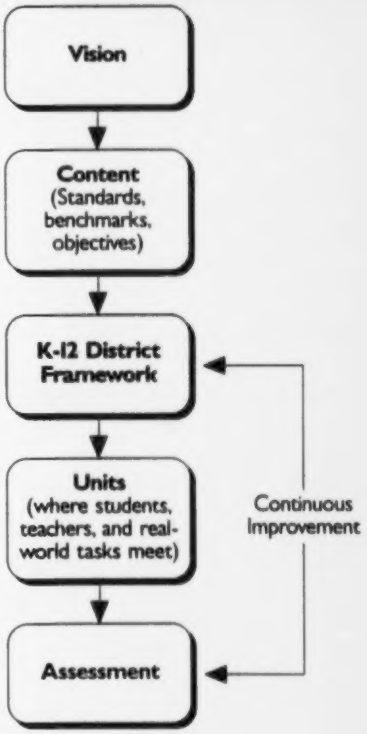
Districts that have effective science curricula generally follow a course of planning similar to that described in the previous section. They work out their vision and goals, and decide what they want students to learn and how that learning will be organized. Then, they look for instructional materials that help teach to their learning objectives.

This organized plan of what students should learn usually takes the form of a district "scope and sequence," sometimes referred to as a district curriculum framework. The plan shows the units they want to teach, the objectives those units will address, and the connections they envision between units and between subjects.

Creating a district curriculum framework is not an easy process. There is no one right way that guarantees success. Curriculum committees debate and talk and plan and negotiate and compromise and try out various configurations until they find a framework that feels comfortable for the majority. They try to find a balance between what teachers want to teach, what the state objectives indicate are important learnings, and what appropriate instructional materials are available for teaching. The result is a framework that shows what will be taught in each grade and that leads to improved student learning of knowledge and skills the district considers important.

The framework can be used to provide a clear overview of the science curriculum to other teachers, parents, and concerned community members. The following sections provide several samples of district curriculum frameworks to help you consider the shape of your own K-12 curriculum.

> *A curriculum is more than just a listing of objectives matched to grade levels. It is a tool for moving along a student's understanding from unit to unit and grade to grade.*


Vision
Content (Standards, benchmarks, objectives)
K-12 District Framework
Units (where students, teachers, and real-world tasks meet)
Assessment
Continuous Improvement

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The Elementary Curriculum

> *"Make it as simple*
> *as you can,*
> *but not any simpler."*

The elementary science curriculum is, at best, an articulated set of experiences that acquaint students with the natural world and the ways that scientists view it. The curriculum is usually built from blocks or units of instruction. These may be composed of commercially available units, chapters from textbooks that have been infused with hands-on activities, sets of activities passed from teacher to teacher, or special projects of various kinds.

The charts on the following pages are examples that show how complete K-4 curricula might be organized. The one below is a sample made up of several units purchased commercially (ordering information is listed in the appendix); state objectives are listed explicitly for each unit.

One possible K-4 district curriculum framework (scope and sequence) using commercially available units

	Kindergarten	1st Grade	2nd Grade	3rd Grade	4th Grade
Life Science Units	GEMS *Tree Homes* GEMS *Ladybugs*	STC *Life Cycle of Butterflies* OR STC *Organisms*	GEMS *Terrarium* Habitats	MDE *Running on Plants*	STC *Microworlds*
obj's	LT 1, 2, 4; LT 1, 3; Eco 1, 2; Evo 2; C1, 2, 5; R 2, 4	LT 1, 3; Evo 2; C 1, 2, 5; R 2, 4	Eco 1, 3, 4; LT 1, 4; Evo 2; C 1, 2, 5; R 2, 4	LT 1, 3, 5; C 1, 2, 4, 5; R 2, 4, 5	Cells 1; C 1, 2, 3, 5; R 3, 5
Physical Science Units		MDE *Constructing Toys & Concepts*	FOSS *Balance & Motion*	STC *Sounds* WOBS *Light, Color & Shadows*	STC *Chemical Tests* AIMS *Mostly Magnets*
obj's		ME 1; CM 1, 3; MO 1; C 1, 2, 5; R 1-4	MO 1, 2, 3; C 1, 2, 3, 5; R 2-4	WV 1, 2; C 1, 2, 3, 5 R 2-4 WV 3, 4, 5; C 1, 2, 5; R 2-4	ME 1, 3; CM 1, 2; C 1, 2, 5 ME 5; C 1-6
Earth Science Units	WOBS *Water & Ice*	WOBS *Rocks, Sand, & Soil*	MDE *Weather in Our Neighborhood*	STC *Rocks & Minerals* District: *Astronomy*	MUCC (K-4) *Project WISE*
obj's	Hyd 1, 4; C 1, 2, 5; R 2, 4	G 2, 4, 5; C 1, 2, 5	AW 1, 2, 4; C 1-6; R 2-5	Evo 1; G 1-6 SS 1, 2	G 6; Eco 5; C 1, 2, 5, 6

For a list of state science objectives abbreviations, see p.22. See the resource section on Instructional Materials for a key to the abbreviations used for the teaching units.

The chart below shows Midland Public School's elementary scope and sequence. Midland's framework is organized around the state science standards (which are the same as the topics found in the *Michigan Essential Goals and Objectives for Science Education*); they developed most of their own units to match the benchmarks/ objectives, using grant money.

Your district's chart may be different from the sample charts in various ways, perhaps having two blocks of physical science in 2nd grade, or two blocks of earth science in 1st grade. **The important aspect of these charts is that they lay out the entire scope and sequence, so educators can coordinate the curriculum between grades; see that the state objectives are addressed *adequately and appropriately;* and conveniently display the curriculum for parents, the school board, and other stakeholders.**

What do districts like Midland consider when constructing these charts?

- Which benchmarks/objectives do teachers and other members of the curriculum committee feel should be addressed at each grade?

Midland Public Schools K-4 Curriculum Framework

	Kindergarten	1st Grade	2nd Grade	3rd Grade	4th Grade
Cells				Cells (Magnifiers)	
Organization of Living Things	Plants, Animals, Senses	Life Cycle of a Bird	Plants	Life Cycle of a Butterfly	Life Cycle of a Plant
Heredity		Offspring Resemble Parents		Offspring Resemble Parents	
Evolution				Fossils	
Ecosystems			Food Chains		Ecosystems Food Webs Energy Transfer
Matter & Energy	Classification Based on Observable Characteristics	Magnets		Magnets Electromagnetism Electricity	
Changes in Matter					Properties of Matter
Motion of Objects			Forces & Simple Machines		Forces & Simple Machines
Waves & Vibrations	Light Sound	Light	Sound	Light/Shadow Transparent Opaque	
Geosphere		Rock & Solid Earth			
Hydrosphere					Properties of Air and Water
Atmosphere			Weather		Weather
Solar System Galaxy & Universe		Astronomy			

- Which units would teachers like to teach? (When new units are added to the curriculum, appropriate in-service education needs to be provided to help teachers prepare.)
- What new units should be developed? Units can be based on natural phenomena and systems, technologies, and everyday scientific events that students should be able to explain, describe, make predictions about, or design solutions for. For example, units can be based on clouds and storms, colors and shadows, the growth of trees and flowers; cars and planes, telephones and TV's, the electrical wiring or sewer systems in their homes; eating food and growing, watching the stars come out at night, making sounds with musical instruments, and many more. The list is endless, limited only by your abilities—and your students'—to observe and explore the natural world.
- Are there appropriate teaching materials available for the existing and new units?
- Are the experiences planned for each year *developmentally appropriate* for students? The essays in MEGOSE provide a research base for determining this.
- What prerequisites for upper elementary units need to be taught in lower elementary units?
- What connections can we help students make across grades that deepen their understanding of the natural world and support their learning in other subjects?

> *What does it mean to "adequately and appropriately" address state objectives? Certainly it means more than, for example, just showing a video where the objective is discussed, or more than just having students see the words of the objective written on the board. Adequately and appropriately addressing the objectives happens when a vast majority of students learn them well, so they can use them to solve problems and apply them to explain the phenomena, systems, and events of the natural world.*

Managing an Elementary Science Program

As soon as you decide to adopt a new science curriculum, questions about equipment begin. Who pays for or supplies the equipment? Where do you get the items? How do you keep track of items so you have things when you need them? Can some items be shared among teachers?

These are all difficult questions. Some districts have been able to purchase everything they need, some expect individual teachers to purchase supplies out of their own pockets, while others find it necessary to ask students to bring many science supplies from home.

Managing science supplies seems to be the hardest part of a hands-on curriculum. Kits of equipment, made up especially for a single unit and replenished every year, are easy for teachers to handle. Some ISDs or Mathematics and Science Centers (listed in the appendix) make up kits for their region. Some curricular materials come with kits. Others allow you to buy kits from a commercial supply house.

Many teachers like having a central location in their building to hold all the science supplies. Others have had the unpleasant experience of not finding what they want in the central location when they need it. Some districts have hired teacher aides to manage science supplies as one of their duties, while others have enlisted the volunteer help of parents.

Equipment is such an important part of a hands-on/minds-on curriculum that your planning must involve a satisfactory way to manage it. You must also find the political will in your district to make science supplies a regular part of the district budget.

The science specialist

Some districts allow teachers who have cultivated special expertise in particular science units to teach those units to all the students in their grade level, or in several grades. They become science specialists. They may teach science to another teacher's class while she or he teaches mathematics or social studies to both classes. Specializing reduces the number of preparations for an individual teacher and allows the teacher to become more proficient with new units more quickly. It also assures a place in the busy elementary day for science.

On the other hand, some teachers prefer to teach science as part of the regular elementary curriculum, so they can build on opportunities to discuss science when something scientific about everyday life comes up in reading, writing, social studies, art, or mathematics. Each district has to weigh the pros and cons of the specialist approach to teaching science.

School-wide science

Some schools have made science their focus. They create an exciting hands-on/minds-on science curriculum—often focused each year around the same theme across all grades. They connect their literature, writing, art, social studies and mathematics programs to their science units, to the extent possible. And they involve parents and other community members as partners in everything they do.

See the resource section for more help on planning your curriculum.

The Secondary Curriculum

The textbook is
not the curriculum.

Constructing a district curriculum framework for the secondary grades is an essential activity for the entire science staff. The process of laying out and looking for connections between the courses, projects, and units taught at each grade helps everyone consider exactly what knowledge and skills you intend to teach, and how they can be organized across the grades. It leads away from a reliance on the textbook and its table of contents as the only guide to your district's curriculum, and helps you consider whether your courses adequately address the state science standards and benchmarks (goals and objectives.)

Warren Consolidated Middle School Curriculum framework using textbook chapters and supplemental materials

	5th Grade	6th Grade	7th Grade	8th Grade
A	Constructing & Reflecting **Science Process Unit** *Hello* (Nat'l Geo.) 8 wks	Waves & Vibrations **Wave Energy** (MacMillan #33) *Windows on Science* (Optical Data) 8 wks	Universe, Galaxy & Solar System, Evolution **Origin of the Universe, Solar System & Earth-Moon System** (MacMillan #37) *Windows on Science* (Optical Data) 7 wks	Constructing & Reflecting (Prentice-Hall) *Product Testing* (Consumer Reports) 7 wks
B	Motions of Object **Forces at Work** (MacMillan #25) *World In Motion* (SAE) 10 wks	Energy **Electricity and Magnetism** (MacMillan #28) *Taking Charge* (NSTA) 6 wks	Geosphere, Evolution **Earth Changes Through Time** (MacMillan #35) *Convection* (GEMS) 4 wks	Matter **Matter: Building Block of the Universe** (Prentice-Hall) *Solutions/Pollution & Toxic Waste* (CEPUP) 15 wks
C	Living Things, Heredity, Evolution, Cells **Plants & Animals** (MacMillan #12) *GROWLAB* (NGA) 9 wks	Matter **Changes in Matter** (MacMillan #28) *Taking Charge* (NSTA) 10 wks	Geosphere, Evolution **Earth Changes Through Time** (MacMillan #40) *Windows on Science* (Optical Data) 8 wks	Energy **Motions of Objects** (Prentice-Hall) *Methods of Motion* (NSTA) 8 wks
D	Weather/Atmosphere **Air, Weather and Climate** (MacMillan #27) *Weather* (Nat'l Geo.) 9 wks	Cells, Living Things, Heredity, Evolution **Simple Organisms and Viruses** (MacMillan #31) *Small Things* (ESS) 10 wks	Hydrosphere, Evolution, Motion of Objects **Oceans in Motion Groundwater** (MacMillan #34) (CEPUP) *The Water Planet* (NSTA) 8 wks	Energy **Heat Energy** (Prentice-Hall) *Evidence of Energy* (NSTA) 6 wks
E		Cells, Living Things, Heredity, Evolution **Plant Kingdom** (MacMillan #30) *GROLAB* (NGA) 6 wks	Living Things, Matter/Energy, Geosphere, Hydrosphere **Earth's Ecosystem** (MacMillan #36) 9 wks	
F	Review of 5th grade MDE goals and objectives 3 wks	Review of 6th grade MDE goals and objectives 3 wks	Review of 7th grade MDE goals and objectives 3 wks	Review of 8th grade MDE goals and objectives 3 wks

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The curricula in middle schools and high schools is usually made up of year-long or semester-long self-contained courses—some required and some elective (although this tradition is not followed everywhere). The courses typically follow the structure of the disciplines: biology (or life science), chemistry, physics (or physical science), maybe earth science or astronomy—with a few courses having names like general science, and a few courses designed for highly successful students, often in biology-related areas, like "anatomy and physiology" or "ecology."

This pattern has been called the "layer-cake" approach because students are treated to a layer of biology, then a layer of chemistry, then a layer of physics, etc. (There is a play on words involved in this label, too: Some science teachers claim that a layer-cake approach is based on the old philosophy that students learn by layering more and more information into their heads, on top of what already exists.)

There are, however, pros as well as cons to the layer-cake approach. At its best, it allows connections to be made across topics or units within a single discipline, such as recognizing that cellular respiration takes place in plants (perhaps learned in a unit on botany or plant growth) as well as in animals (perhaps learned in a unit on human physiology); or that the gravitational force that makes baseballs follow their trajectory is similar to the electrical force that holds atoms together—they both obey an inverse square law. A layer-cake approach is also easier to staff, since teachers are usually educated primarily in one discipline.

But there are advantages to non-layer-cake approaches, where units from several different disciplines are taught in the same year. Warren Consolidated School District has a middle school framework that illustrates this non-layer-cake approach. One advantage is that different kinds of connections can be made across the traditional discipline boundaries, like seeing how the concept of conservation applies in physics, chemistry, biology, and earth science, or how the broad idea of systems plays out in technology, ecology, and astronomy. Another is that the diversity among the sciences may provide something of interest for many different students.

The National Science Teachers Association recommends a non-layer-cake approach to the secondary curriculum—they call it a "coordinated" approach—so that life, earth, and physical science can be taught several times during 7th through 12th grade, returning to each set of topics at a higher level of sophistication. They recommend that 7th-9th grade science be primarily descriptive, conceptual, and empirical, so that 10th-12th grade science can approach each topic in a more theoretical and quantitative way. They believe that students will develop a deeper, more intuitive and conceptual understanding of important science and its applications if the curriculum is coordinated in this way. This approach also allows students to learn, for example, the chemistry they need to understand cell biology, or the physics they need to understand movements and phenomena of the earth's crust.

> *The science curriculum in U.S. schools is a mile wide and an inch deep.*
>
> [illegible]

One sample curriculum framework for middle grades, based on MEGOSE topics (the content standards), showing sources of instructional materials. No grades are suggested in this table, giving you the option to place each unit wherever your curriculum committee chooses.

	Middle School Physical Science	state benchmarks/ objectives	**Middle School Earth Science**	state benchmarks/ objectives	**Middle School Life Science**	state benchmarks/ objectives
	Matter & Energy		**Weather & Atmosphere**		**Plants & Cells**	
Units and possible instruc. mat'ls:	LHS GEMS *Chemical Reactions*	ME4, C7, 8, 10, 11, 12	LHS GEMS *Global Warming & the Greenhouse Effect*	AW 5, 8; Eco 11; CM 7; C7, 8, 10, 11, 12	MDE *Lives of Plants*	Cells 3, 4; LT 6, 7, 8; C7, 8, 10, 11, 12; R8
	STC *Electric circuits*	ME15; C7-12; R8;			STC: *Plant Growth & Development*	LT6, 7, 9; C7, 8, 10-12
	STC *Magnets & Motors*	ME16; C7-12; R8	LHS GEMS *Acid Rain*	R6, 7, 8, 9		
	LHS CEPUP *Refrigeration*	ME8, 13; CM4, 7; C7-12; R8, 9				
	Motions of Objects		**Hydrosphere**		**Animals**	
Units and possible instruc. mat'ls:	AIMS *Machine Shop*	MO4, 5, 6, 7 C7, 8, 9, 10, 11, 12	LHS CEPUP Groundwater: *The Fruitvale Story*	Hyd 7, 8; C7, 8, 10, 11, 12; R6, 7, 8, 9	NSTA *Earthworms*	Evo 2; LT 6, 9; C7, 8, 10-12; R6, 8
			NSTA *Project Earth Science: Meteorology*		NSTA *Pillbug Project*	Evo 2, LT6; C7, 8, 10-12 R6, 8
	Changes in Matter		**Geosphere**		**Ecology**	
Units and possible instruc mat'ls:	MDE *Hard As Ice. Steamed Up!*	H5, ME8, 12, CM1, 4, 8; C7, 8, 10 R6, 10	LHS CEPUP *Waste Hierarchy*	CM 6, 7; H7 C7, 8, 11; R6, 8, 9; G6 (elem)	IES *Eco-Inquiry*	Eco 6-12; C7, 8, 10-12; R6, 8
	LHS GEMS *Acid Rain*	AW8; Eco 11; CM7; C7, 8, 10, 11, 12; R6-9				
	LHS CEPUP *Plastics in Our Lives*	ME11, 12; CM7, 8; Eco 11; C7, 8, 11, 12; R6-9				
	Investigating Chemical Processes: Your Island Factory	CM5, 7; Eco 11; C7, 8, 11, 12; R6, 7, 9				
	Investigating Hazardous Materials	CM6, 7; Eco 11; C7, 8, 11, 12; R6, 8, 9				
	Household Chemicals	ME10; CM5; Eco 11 C7, 8, 10, 11, 12; R8				
	Waves & Vibrations		**Astronomy**		**Human Biology** or **Heredity & Evolution**	
Units and possible instruc. mat'ls:	LHS GEMS *Hot Water, Warm Houses*	ME8, 13; CM4; C7-12; R6, 7, 8, 9	LHS GEMS *Sun, Moon & Stars*	SS 4, 5		
	Franklin Institute *Light & Color*	WV8, 9	*NSTA Project Earth Science: Astronomy*	(obj's not reviewed)		

A guide to abbreviations for the state science objectives:

C	Constructing New Knowledge
R	Reflecting on Sci. Knowledge
Cells	Cells
LT	Organization of Living Things
Her	Heredity
Evo	Evolution
Eco	Ecosystems
ME	Matter and Energy
CM	Changes in Matter
MO	Motion of Objects
WV	Waves and Vibrations
G	Geosphere
Hyd	Hydrosphere
AW	Atmosphere and Weather
SS	Solar System, Galaxy & Universe

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Connections are critical when they help deepen and strengthen students' understanding, when they reinforce, extend, and enlighten students' performance of your objectives. Whether your district uses a layer-cake approach or a non-layer-cake approach is not as important as the fact that connections are explicitly made across units and grades. Students don't necessarily make these connections without the curriculum and teacher making them clear.

Making connections is only one of the four goals for science education stated in MEGOSE (see p. 5.) All four goals need to be considered to create an effective curriculum. Oxford Public Schools has a new curriculum that blends the layer-cake and non-layer cake approaches to address the four goals. Their curriculum framework is the result of a long process of deliberation, research, and debate among teachers, administrators, parents, and other concerned community members.

Their solution to the curriculum puzzle rests on 8th, 9th and 10th grade science courses that appropriately and adequately address all MEGOSE objectives for all students. 11th and 12th grade offerings allow students to specialize, to take additional courses for college or other post-secondary education, or satisfy their interests. If they desire, students are allowed to take Biology 1 concurrently with 9th or 10th grade science. How does Oxford's curriculum accomplish the MEGOSE goals?

Basic Tenets of the National Science Teachers Association Scope, Sequence, and Coordination Project

1. **To provide science learning in four subject areas each year: biology, chemistry, physics, and the earth and space sciences;**
2. **To explicitly take into account students' prior knowledge and experience, as expressed in their preconceptions and metaphors (much of this is available in the literature);**
3. **To provide a sequence of content, and the learning of it, from concrete experience and descriptive expression to abstract symbolism and quantitative expression;**
4. **To provide concrete experiences with science phenomena before the use of terminology that describes or represents those phenomena;**
5. To revisit concepts, principles, and theories at successively higher levels of abstraction;
6. To coordinate the four science subjects so as to interrelate basic concepts and principles;
7. To utilize the short-term motivational power of relevance by connecting the science learned to subject areas outside of science (such as history, art, and music), to the practical applications of how devices in our technology work, and to the challenge of solving those personal and societal problems that have relevant underlying scientific components;
8. To utilize the long-term motivational power of sudden and profound understandings of science and of the awe that stems from comprehension of the power and universality of a relatively small number of fundamental principles of science;
9. To greatly reduce topical coverage, with an increased emphasis on greater depth of understanding of those fewer fundamental topics; and
10. To create assessment methods, items, and instruments to measure student skills, knowledge, understandings, and attitudes, both for program evaluation and the requirement of assigning grades, which are fully consistent with tenets 1-9.

Goal 1—Understanding is accomplished by reducing the amount of factual detail presented in each course, in order to focus on a conceptual understanding of the main ideas and their applications and uses, by drawing out connections across the disciplines (e.g. studying "germs" in 8th grade, and the immune system in 9th; studying the physics of light and color when studying astronomy), and by recognizing and addressing the prior knowledge that students bring with them to class.

Goal 2—For All Students is accomplished by creating classes that all students are required to take, that engage all students, that address all of the MEGOSE objectives, and that develop scientific literacy rather than being remedial or trivial.

Goal 3—Useful and Relevant is accomplished by ensuring that all courses focus on applications and uses of knowledge, understanding of real-world phenomena, and creation of solutions to real community science-based issues.

Goal 4—Interdisciplinary is accomplished by creating units within courses that bridge the traditional boundaries of the disciplines (as the astronomy example cited above), and by incorporating reading, writing, mathematics, technology, and connections to social and community issues whenever possible.

What do districts like Oxford and Warren Consolidated consider when developing a secondary scope and sequence, or curriculum framework?

Oxford Community Schools Secondary Curriculum Framework

	8th Grade	**9th Grade**	**10th Grade**	**11th Grade**	**12th Grade**
1st semester courses	8th grade science I	earth science	applied physics	biology 1 **or** chemistry 1 **or** physics (all full year) **or** astronomy	biology 2 **or** chemistry 2 **or** physics (all full year) **or** astronomy
topics keyed to benchmarks/ objectives	*heat and energy; recycling; plate techtonics; earth mat'ls; ground water*	*Great Lakes geology; weather & climate; astronomy; light and color*	*electricity and magnetism; nuclear; force and motion; sound*		
2nd semester courses	8th grade science II	life science	applied chemistry	biology 1 **or** chemistry 1 **or** physics **or** geology	biology 2 **or** chemistry 2 **or** physics **or** geology
topics keyed to benchmarks/ objectives	*classification; germs; ecology*	*cell processes; growth & respiration; immune system; heredity; evolution*	*chemistry*		

✓ **The objectives:** How will all students have sufficient opportunities to learn the state science objectives? The charts in this section break year-long courses into units, so that each can be checked for its alignment with the state science objectives. Completing a chart like the ones on these pages helps you do this. You may want to use the chart on p. 29 to tally the objectives you teach across units, to see if all of the state objectives are addressed.

✓ **Course structure and prerequisite knowledge:** How will you organize the curriculum across the secondary years to cover earth science, as well as life science and physical science, so that students have the prerequisite science knowledge and skills they need for all units? Will you have a "layer-cake" curriculum (one year of biology, one year of physics, one year of chemistry, one year of earth science), or will you interweave subjects during one year (e.g. a 4-week unit on heat and energy transformations, an 8-week unit on basic chemistry, a 6-week unit on cell life processes, a three-day seminar on environmental issues, etc.)? There are pros and cons to both approaches, as noted above.

> *Learning takes time. While some learning objectives might be accomplished in one or two lessons, many important learnings require several years of study in many different contexts. Your curriculum should allow students the time they need to learn complex knowledge and skills.*

✓ ***Constructing* and *Reflecting* objectives:** How will you organize the curriculum to teach students about the nature and processes of science, as well as the content and its applications? The state science objectives are a good guide to learning in these areas, having sections on "constructing scientific knowledge" and "reflecting on scientific knowledge." But, you need to determine how each course or unit will address them. These objectives will not be learned in one short unit on "the scientific method." They will have to be practiced and discussed over and over in different contexts. As you build your secondary curriculum framework, consider how the "constructing" and "reflecting" objectives enter into all of the courses or units you teach.

✓ **8th grade articulation:** How will the middle school science curriculum integrate with the high school curriculum? Remember that the High School Proficiency Test is given in the middle of 11th grade, so students need opportunities to learn the state high school objectives by then. In many districts, the 8th grade curriculum is coordinated with the high school curriculum to provide more opportunity for students to learn the high school objectives.

✓ **Amount of material in each course:** How will you deal with the great variety of interests and abilities in science in these grades? Many teachers respond to this mix of interests by jumping from topic to topic, trying to find something to engage everyone. This approach can backfire, however. It risks not concentrating on any topic well enough to be truly satisfying, and students develop little skill or real depth of understanding. This is the pitfall of trying to cover too much: watering down and glossing over important science. Many secondary teachers are beginning to give themselves permission to slow down and not try to cover everything, but to teach in an engaging and thought-provoking way.

✔ **Collecting and using data:** What will your lab activities be like? Will they allow students to investigate important questions and collect useful data, or will they be used just to verify the laws and facts in the textbook?

The two curriculum frameworks shown on p. 27 and 28 illustrate both a "layer-cake approach" and a "coordinated" approach. These frameworks were developed specifically to illustrate the two approaches—the units listed in the charts do not presently exist (except for those which have publishers' names attached) but they could be developed from existing textbook chapters and teacher-developed and collected activities. See the section on units of instruction, pp. 35-37, for more ideas about creating individual units.

Many districts include the second half of their 8th grade science curriculum as part of their complete "high school" sequence. Once the 8th grade MEAP is given in late February, the rest of the year can be devoted to the high school benchmarks/objectives.

The charts illustrate several ways of connecting units and building on ideas:

- Some units are prerequisite for others. For example, the MDE unit *Chemistry That Applies* is needed to understand the chemistry of cellular respiration in the MDE unit *Food, Energy, and Growth.*
- Some units are linked together by a common theme. The theme is really a set of important ideas or concepts. Some examples are: energy (its forms and conversions), forces and their effects, populations and their dynamics, diversity, the uses of technology, and humans' effects on the environment.

Staffing and scheduling

Those districts that decide to teach a mix of topics from the disciplines each year need to determine how to assign teachers to classes, especially since secondary teachers are mostly educated and credentialed in only one discipline. Should science teachers become generalists, able to teach from life science, earth science, chemistry and physics? Should teachers team together to provide instruction in each area? Should students rotate among teachers during a single year? All of these approaches, and more, are being tried in schools across the state. Some are being blended with a move to block scheduling, where students take only 3 or 4 courses a day, for 1 1/2 hours or longer. No one has yet found the perfect solution to these management questions.

Don't forget Earth Science

Although it occupies a full third of the "using scientific knowledge" objectives in the state science objectives, many schools have left earth science out of their secondary science curriculum. It is important to make a place for it in your secondary science curricula. How you include it is up to you: You might have all students take it in 9th grade, or weave it into a general science course for both 8th and 9th grades, or find some other creative solution. Just don't forget it!

A sample "coordinated" curriculum framework

	8th grade chemistry, biology, and physics	major objectives*	**9th grade** earth science, physical science and technology	major objectives*	**10th grade** biology and earth science/environmental science	major objectives*
Unit 1	*Chemstry That Applies* an intro to chemistry (needed for units 5 & 6)	CM9, 12, 13, 14, 15 ME19, 21	Shape of the land; geography, geology, civilization (relates back to 8th gr. unit 2)	Hyd9, G12	Ecology: the big picture of life on earth (relates back to 8th gr. unit 2)	Eco 13-17
Unit 2	Biodiversity and endangered species—*Survival Strategies*, Bronx Zoo	Eco 13, 15 16, 18	Climate, water, and weather	Hyd9 AW9, 10, 11; E18 SS10	Earth materials: origin, use, and recycling (needed for unit 3; based on 8th gr. unit 1)	G14, CM12
Unit 3	Physics of motion: force, acceleration and the Space Shuttle	MO8, 9	Landforms and upheavals; how the earth changes over time	G13	Risks and benefits of everyday substances: environmental pollution (river project)	Eco18; AW12; Hyd10
Unit 4	Electricity and magnetism: How things work	CM15; ME21, 23 24	Sound recording devices (relates to 8th gr. unit 4)	CM15, ME21, WV12, 13, 16, 17, 18, 19, 20	Disease: germs, immune system, and technology (relates back to 8th gr. unit 5)	LT10, 11, 13, 14
Unit 5	*Food, Energy and Growth:* cells, human body systems, nutrition	Cells6, 9, 11, LT9, 12; CM11; ME21	Energy and technology: doing work (related back to 8th gr. unit 4)	CM11, 15, 16; ME21, 22	Individuals: characteristics, reproduction, heredity	Her4, 5, 6
Unit 6	Chemical elements: families of reactions & atomic structure (builds on unit 1)	ME18, 20	The universe and our place in it: how stars shine (combines nuclear physics with astronomy)	WV14, 15, 16, 17, 18 SS7, 8, 9, 11, 12; CM10,14	How species change over time (*Jurassic Park;* BSCS Evolution)	Evo4, 5, 6

**Constructing* and *Reflecting* objectives need to be woven into each unit of instruction.

School-wide themes

Some schools use school-wide themes as a curricular focus, to provide a coordinating emphasis to their program and real-world relevance for students. Curricular focuses include: medicine and health; technology/how things work; weather and its effects; the scientific enterprise; the environment; space and aviation; manufacturing; transportation; agriculture and food; water resources; etc. Schools that use curricular themes often choose ones that are related to their local environment or their regional business and industry centers. In this way, they also help prepare their students for post-secondary education and career opportunities.

Schools that have "coordinated" curricula often buy one classroom set of a textbook or text series, then purchase additional specific hands-on units and other supplemental materials to fill in where their textbooks leave off.

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A sample "layer-cake" curriculum framework

	8th grade Physical Science	major objectives*	**9th grade** Earth Science	major objectives*	**10th grade** Life Science	major objectives*
Unit 1	*Chemistry That Applies* (MDE)	CM9, 12, 13, 14, 15 ME19, 21	Landforms and upheavals: how the earth changes over time (forces)	G12, 13	Individuals: characteristics, reproduction, heredity	Her4, 5, 6
Unit 2	Chemical elements: families of reactions & atomic structure	ME18, 20	Quality of water, air and land	ME17 Hyd8, 10 AW12	*Food, Energy and Growth* (MDE)	CM11 ME21 LT12 Cells 6
Unit 3	Energy and technology: doing work	CM11, 15, 16 ME21, 22	Climate, water and weather	Hyd9, AW9, 10, 11; E18 SS10	Disease: germs, immune system, and technology	LT10, 11, 13, 14
Unit 4	Physics of motion: force and acceleration	MO8, 9	The universe and our place in it: how stars shine	WV14, 15, 16, 17, 18 SS7, 8, 9, 11, 12	Ecology: the big picture of life on earth	Eco13-17
Unit 5	The Space Shuttle: force, motion and technology (NASA)	MO10, 11	Earth materials: origin, use, and recycling	G14	Biodiversity/endangered species (Bronx Zoo)	Eco13, 15, 16, 18
Unit 6	Electricity and magnetism	CM15, ME21, 23, 24			Pollution and its effects on ecosystems	Eco18
Unit 7	Sound recording devices	CM15 ME21 WV 12, 13 16, 17, 18, 19, 20			How species change over time (*Jurassic Park;* BSCS Evolution)	Evo4, 5, 6
Unit 8	Atomic and nuclear physics: STS	CM10, 14				

Constructing and *Reflecting* objectives need to be woven into each unit of instruction.

Moving towards a new curriculum

It takes time to get a new curriculum to work well, so take your time. Move slowly. Take small steps. Get everyone involved as soon as possible. When you create a new curriculum, you are committing your school to new ways of thinking about content and connections, new ways of teaching and learning, and new ways of assessing.

What can you do?

Use the charts on pages 29 and 38 to plan your curriculum revision.

Copy this blank chart to design your own district curriculum framework.

	Grade _____	obj's	Grade _____	obj's	Grade _____	obj's
Unit 1						
Unit 2						
Unit 3						
Unit 4						
Unit 5						
Unit 6						
Long-term projects						

Coordinating A Single Year's Curriculum

What broader goals can be accomplished by looking at how the entire year's science curriculum falls into place?

After decisions are made about what to teach at each grade, and a useful district curriculum framework is established, those who teach a single grade or a single course can look more closely at one entire year. They can ask: "How can the units of this grade or course be coordinated to help students learn those objectives or benchmarks that are not easily learned in one unit?" "How can this year's curriculum help students deepen their understanding of complex themes that run throughout science, and learn complex skills of investigation and problem solving?" "How can our course build on and extend students' working knowledge of mathematics, English language arts, social studies, and the arts?"

A second chart that looks at just one year's curriculum has become a useful tool for teachers planning a single grade. The sample below illustrates how the questions posed above can be worked through to provide a deep understanding of the broad goals of a single year's curriculum. Several types of broad goals are addressed here:

Skills and habits of mind: Create your curriculum so students develop competencies in the "constructing scientific knowledge" and "reflecting on scientific knowledge" benchmarks over time. Choose several of these benchmarks for each year, and focus on those. Take "Generate questions about the world" as an example: Have students do this throughout each unit. Pose questions yourself at the start of each lesson, whether the lesson plans you are using do this for you or

A sample year-long curriculum

3rd Grade UNITS	*Running on Plants* (MDE)	Sounds (NSRC STC or Insights)	*Volcanos and Earthquakes*	*Construction and Testing* (BSCS SFLL)	*Nutrition and Dental Care* (BSCS)
Real-world Contests	Growing	Sights and sounds of the environment	Sights and sounds of the environment	Towers and bridges	Growing and maturing
Major goals for 3rd grade	1. To expand students' appreciation and understanding of the natural world, in both science and geography; 2. To have students develop their abilities to ask questions; 3. To reinforce mathematics ideas about representing data; 4. To help students develop good eating habits.				
Constructing and reflecting objectives	C1. Generate reasonable questions about the world, based on observaton. R4. Develop an awareness of and sensitivity to the natural world. C6. Construct charts and graphs and prepare summaries of observations.				
Other subject area connections	Mathematics: Measuring and graphing the growth of plants	Music (sounds)	Geography: Where in the U.S. are volcanoes and earthquakes?	(Can build on 1st gr. *Constructing Toys and Concepts)*	Health and safety
Writing across the curriculum	Descriptive	Resource/ Research	Explanation	Descriptive (with drawing)	

not. Challenge students to ask questions throughout their science period. Hold them responsible for good questions. Keep a running list on the board. Let them follow through on several questions, exploring different options for finding answers.

Real-world contexts: Help students learn to use scientific ideas, not just memorize abstract concepts and definitions. The curriculum can do this by threading real-world contexts throughout various units. Examples of real-world contexts include ecosystems (dunes, rivers, wetlands, forests), thunderstorms, food and agriculture, water resources, household appliances, transportation, pets, and zillions of others. While these may or may not be the prime focus of a unit, they must be emphasized to keep science from being too abstract and theoretical.

> *At all grade levels, field trips out into the real world are crucial for helping students see the connections between what they study in class and what they will encounter outside of school. Field trips make things real for students.*

Rich real-world contexts are a natural basis for a curriculum that shows how the traditional science disciplines are interconnected. Food is one example: To really understand what happens to food after it enters your body, you need to understand both the biology of human body systems, and the chemistry of cell reactions. Another example: If you're familiar with *The Voyage of the Mimi*, you know how the real-world context of an ocean-exploring voyage helps students learn about connections between the sciences. Oceanography is one of many scientific fields that combine elements from life science, physical science, and earth science.

Connections to other subjects: Other subjects have natural connections to science. **Geography,** for example, teaches about the physical features of the earth's surface, so it's highly connected to earth science (geography, weather, hydrosphere) and biology (ecosystems). **Artistic expression** (drawing, movement, music) can be used to represent difficult science concepts. **Mathematics** is used for quantifying science whenever quantification helps deepen understanding. Many **social and economic concerns** have scientific and technological components that need to be understood to make decisions about social and economic issues.

Making connections in this way doesn't carry the load of teaching the other subjects, but it does reinforce them and provide additional meaningful contexts for their use. If you want science class to provide substantive instruction in other areas, you need to plan the mathematics or writing or social studies parts of the science lesson as carefully as you plan the science. In particular, reading for information (very important in the study of science) requires different skills from reading fiction. These skills will need to be taught and practiced. Coordinate these connections with teachers responsible for the other subjects.

Writing in science: Writing is such an important skill for *learning* science that it should have a significant place in science classes. Several purposes for writing can be explored and refined, including:

- **Description:** Students carefully observe and describe a substance, an organism, an object, or an event.

Even creative writing has a place in science.

I am Berkelium,
The element that all forgot.
Useless and unneeded.
Why don't they care about me?
They don't even know my
melting or boiling point.
Or care.
My life is long and pointless.
They made me.
They made me out of other
useless elements.
It's no wonder that I am a
nobody.
My life should come to an end.
I have no purpose as an
element.
I could live to be 100,000.
But why would I want to?
Damn the scientists
In Berkeley, California
When they chemically altered
my brother, Americium,
To create me.
Why?
To them I serve no purpose.
To Earth I serve no purpose.
Because She was not my
mother.
So why?
Why did they make me?
For now there is no way to
erase me. From the Periodic
table.
I wish.
I wish I could disappear from
that table. Forever.
I am Berkelium,
The element that all forgot.
Goodbye.

Sloan Tomlinson
East Lansing High School

- **Explanation:** Students make a prediction or claim, present a theory, or explain lab results, supporting their contentions with evidence.
- **Cause and effect:** A type of explanation, students describe what lead up to a phenomena or event, making connections that reasonably explain the phenomena or event.
- **Information:** Students gather information from sources (e.g., print, video, lecture) or investigations, then synthesize and re-tell it.
- **Persuasion:** Students take a position on an issue, and support their position with reason and evidence.

Doing mathematics in science

Important school science can be done without using mathematics, just as good mathematics can be done without placing it in science contexts. But students' understanding of some science ideas can be deepened by seeing mathematical relationships in them. For example, in high school, some aspects of electricity can be fleshed out by describing and working with the relationships between resistance, voltage and current. In middle school, concepts of force and motion can be understood better by probing the simple mathematical expression of the relationship between force, mass, and change of speed: $F=ma$. Even at the elementary level, counting, charting, and graphing are appropriate ways to describe certain phenomena.

The key is to use mathematics when it serves the purpose of helping students understand science better, not when it takes the place of fundamental conceptual understanding. Just learning how to manipulate equations is not a substitute for learning what the equations mean, where they come from, and when they should be used.

Thematic science

Great minds disagree greatly about thematic science. While some advocate constructing units of study around the overarching themes of science (like "systems", "change", or "models") there have been some failures of these curricula—probably because these themes are very complex. Others advocate building units on important concepts that emerge in many disciplines, such as energy, conservation, or evolution. Still others look to broad real-world contexts or problems, such as food, thunderstorms, power, growing, waste disposal, water pollution, or disease as a basis for a comprehensive curriculum that spans science, mathematics, language arts, social studies, and the arts.

Constructing thematic units is much like walking a tight rope—a difficult balancing act with danger on all sides. It can be done, but it requires a great deal of thought, creativity, and some sacrifices. If it isn't done well, the science content can be trivialized.

Employability Skills

All classes should strive to help students develop career and employability skills, including:

- applied communication and mathematics skills
- developing and presenting information
- understanding social and technical systems
- organizational skills
- personal management (of one's responsibilities and time)
- teamwork
- career planning
- problem solving
- negotiation skills

Using textbooks constructively

Most high schools (and many elementary and middle schools) use traditional textbooks as the basis of instruction. While some students learn well from traditional textbook-based teaching approaches (the cycle of read or listen to a lecture, take notes, then take tests), many students do not. And most students do not develop true science literacy from this approach—they are not able to apply what they learn to real-world situations.

If your secondary curriculum is text-based, find good lab activities to go with each chapter. Supplement the text with field trips, projects, writing assignments, and library research. Determine what the important ideas and concepts are in each chapter, and minimize the rest. The text is only a repository of knowledge, not a classroom curriculum. Teachers make a unit their own as they add activities and projects to the knowledge outlined in the text—as they help students make sense of it. Lecture and recitation, using a textbook all by itself, is clearly not the most advanced form of learning.

f your secondary curriculum is text-based, find good lab activities to go with each chapter. Hands-on science at the secondary level is important for all students. The nature of science is that it deals with the phenomena, systems and events of the natural world, and uses tools to investigate them—it is not just theoretical, and should not be taught without having real-world contexts in front of students at all times.

East Lansing Public Schools 8th grade curriculum, combining the textbook and supplemental units

	Unit 1	Unit 2	Unit 3	Unit 4
Topic/Time	**Chemistry** **8 weeks**	**Human genetics** **8 weeks**	**Endangered Species** **8 weeks**	**Acid Rain/ Greenhouse Effect** **8 weeks**
Objectives Using, Constructing, and Reflecting	Changes in Matter, and Energy, Constructing, Reflecting	Heredity, Constructing, Reflecting	Living Things, Ecology, Constructing, Reflecting	Changes in Matter, Atmosphere & Weather, Waves & Vibrations, Ecology, Constructing, Reflecting
Real-world Contexts	Rusting, burning, chemical manufacturing	Genetic diseases	Species of Michigan, the U.S., and other countries	Environmental concerns
Connections	ties to earlier studies of molecules and physical changes	ties to health studies	builds on genetics	builds on chemistry unit, ties to endangered species
Instructional Materials	MDE *Chemistry That Applies* with other textbook material	1 chapter from text	Bronx Zoo Survival Strategies	GEMS Unit
Goals	Help students understand the concept of balance in different contexts (chemical balance, ecological balance, environmental balance) and the concept of conservation (of mass in chemical reactions, of natural resources in several different contexts.) Help students learn to pose and investigate scientific questions, and evaluate scientific claims.			

Houston SS&C Project Eighth Grade Overview

Fall Semester

Block	Duration	Subjects
Block I **Streams**	4 weeks	**Earth Science** Physics Chemistry Biology
Block II **Disappearing Acts**	2 weeks	**Chemistry** Biology Earth Science Physics
Block III **Hidden Structures Part 2**	4 weeks	**Physics** Earth Science Biology
Block IV **Envelope of Life**	4 weeks	**Physics** Earth Science Biology Chemistry

Spring Semester

Block	Duration	Subjects
Block V **Fueling Around**	4 weeks	**Earth Science** Biology Physics
Block VI **Parts**	4 weeks	**Physics** Earth Science Biology
Block VII **Time**	4 weeks	**Biology** Earth Science

Copy and use this chart to plan and outline your grade-level curricula.

Grade ______ UNITS					
Contexts					
Major goals for the grade?					
Constructing and reflecting objectives					
Other subject area connections					
Writing across the curriculum					

Planning Units of Instruction

Units of instruction are the basic building blocks of the science curriculum. They can be purchased commercially (see the appendix on instructional programs and units); they can be developed out of textbook chapters that are enhanced with activities; or they can be "home-made" and passed from teacher to teacher.

Commercially available units have several advantages over ones you might create on your own. They have already been thoroughly field-tested and shown to be effective with students. Their directions are often more explicit than locally-designed units, so they can be passed from teacher to teacher without as much additional explanation or support. And some even come with the option of purchasing all the materials and equipment needed in a single kit.

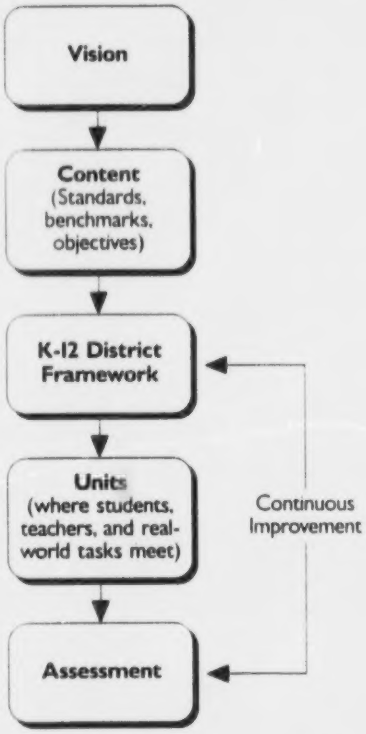
But often districts want to tailor units to their own specifications, or they may not be able to find any commercial units to fit a topic in their scope and sequence, or they may have already purchased a textbook and feel that they have to use it. What follows are some options for developing effective units if you start with a textbook or start from scratch.

If your curriculum is text-based, think of each chapter as a unit, or combine the most important aspects from several chapters into one unit. If you start from scratch, bring together whatever resource materials you have to begin the process.

- Determine what the learning objectives are for your unit, by referring to MEGOSE/Content Standards and Benchmarks. These have been written to be developmentally appropriate for most students. Don't forget to integrate Constructing New Knowledge and Reflecting on Knowledge objectives into your Using Life, Earth or Physical Science objectives.
- Figure out what the topic of your unit actually is. Go deeper than using a standard topic from the textbook, like "optics" or "cells" or "the immune system." Use something like "light and color," or "how the eye works," or "cholera and plagues." Use the MEGOSE essays and objectives/benchmarks for your unit—especially the "real-world contexts" section—to help think about what the topic is. Good topics often have a "hook"—a connection to students' experiences. Knowing the topic and the learning objectives/benchmarks, create one or more "key questions" to guide your unit development and students' learning. Good key questions are engaging to students and open up a topic, rather than prescribe simple answers.
- With the topic, key questions, and learning objectives in mind, get rid of superfluous concepts and terms from any textbook material you might use, in order to concentrate on the main ideas.

Make sure each unit focuses on active learning—engaging the mind while engaging the hands. In preparing each unit,

- *consider student misconceptions and naive theories;*
- *list the major ideas to be learned in each unit, along with the tasks students do to learn them;*
- *introduce real-world contexts as appropriate.*


Vision
Content (Standards, benchmarks, objectives)
K-12 District Framework
Units (where students, teachers, and real-world tasks meet)
Assessment
Continuous Improvement

riting all your own units from scratch is very difficult, time-consuming, and expensive. If you can't find suitable commercial units, take the resources you already have—the hands-on activities, the reading and video support materials, etc.—and turn them into a unit. Make use of the instructional model presented here. Also, thoroughly field test your units, looking for how well students learn from them, not just how easy they are for teachers to use.

- Determine the specific things you want students to be able to do by the end of the unit, with the knowledge they gain as they study it. These become the central "tasks" of the unit. They are related directly to *MEGOSE* objectives/content standards and benchmarks. For instance, for the objective: "Explain how selected systems and process work together in animals and plants," you may develop a student task such as "Explain how the food you put into your mouth eventually gets to the places in your body where you need energy." These specific tasks will give you a clear picture of the kinds of hands-on, reading, writing, and discussion activities that you want students to do in your unit. They will also direct you as you write assessments. Make sure to include multiple contexts and multiple tasks for each objective/benchmark
- Find or create good lab activities and other engaging investigations to go with each chapter. Hands-on science at the secondary level is *not* just for underachieving students. Science *always* deals with the phenomena, systems and events of the natural world, and uses tools to investigate them—it is not just theoretical. This is why hands-on science is so important!
- Find other supplemental materials to help teach each unit, including videos, computer simulations, field trips, and community-related projects.
- Structure the unit according to an instructional model similar to the one presented below.
- Infuse writing opportunities for students into each unit.
- Structure opportunities for students to articulate and think about their ideas related to the topic. *MEGOSE* and AAAS Project 2061 *Benchmarks for Science Literacy* are good guides to typical student naive thinking and misconceptions on many topics.
- Write good assessment items for each unit to find out how well students are learning what you intend to teach. Don't settle on just multiple choice or matching or fill-in-the-blank items—they don't always tell you everything that students really know. Use assessment questions that require students to write about what they know, to describe the phenomena they've been studying in some detail, to explain how things work and why, to make predictions and write about how to test them (see the assessment section, pp. 57-60).

Many engaging and relevant units can be constructed, borrowed, or purchased to adequately and appropriately teach the content standards you set for your students. They can be laboratory-oriented, taking 2 weeks to 2 months to develop certain concepts and skills. They can be research-oriented, taking one day a week for the entire school year. They can be design-oriented, taking several hours a day for an entire week to design and build something useful. The configuration of each unit depends on what you want to accomplish and how much time you have available.

For more information on unit planning, see the SEMSplus module "Unit Planning for Conceptual Change." Ordering information is available in the resource section.

The "Learning Cycle"—an Instructional Model

1) **Establish a problem or question** that is understood by everyone, a problem that engages the mind:

- A social or scientific problem or question;
- Based on objectives already determined by your district;
- Suggested by the teacher or by students;
- Chosen to get students wondering, and to establish a willingness to become involved in investigations and discussions, promising a connection between their present understanding and some future possibilities.

2) **Explore all aspects of the problem,** including the phenomena or system that the problem is about, and the ways students think about it. Establish a common base of experiences and common language for solving the problem or answering the question:

- Explore the real-world phenomena or system that the problem comes from in a "hands-on" way (e.g., with experiments, observations);
- Brainstorm about possible solutions, eliciting students' ideas and confusions;
- Search for additional information, if necessary, and organize it appropriately.

3) **The teacher and students together construct a solution** that makes sense to everyone.

- Teacher introduces and explains new ideas and techniques needed for the solution;
- The hard work of constructing the solution must be the students', through their own reasoning, through discussion with others, and guided by modeling and coaching from the teacher;
- Entertain debate about the appropriateness and justification of the solution—the reasoning and evidence behind it.
- Allow for independent use and practice with the new ideas in several contexts, coaching the students' use of the new ideas as necessary, until students make the solution their own.

4) **Students solidify and extend their understanding** of the problem and its solution by looking at the problem in different contexts and generating new questions that lead to new exploration.

- Apply the solution or explanation in new real-world contexts.
- Look for unresolved questions or problems, and pose them as a way of starting the cycle all over again.

PLANNING SHEET

What do you and your district need to do to improve your curriculum?

Step 1:

Step 2:

Step 3:

Step 4:

Step 5:

SECTION 4

TEACHING FOR SCIENTIFIC LITERACY

Even though months or years of work may have been needed to create your written curriculum, it is teachers who bring it to life and ensure its success. While students ultimately must construct their own meaning from their work in science, it is the teacher who facilitates their learning. Teachers create learning environments that signal to students that something is interesting or important; they set up the conditions for learning tasks and inquiries; they hold students to appropriate standards of performance. Teachers who communicate a genuine regard for their students and model how to do science and how to think about science questions are critical for helping students become scientifically literate.

Techniques for teaching science vary from primary grades to high school, but teaching for understanding basically follows a continuum that begins with teachers modeling the process of inquiry and explanation, and culminates with students being able to inquire and explain independently. Teachers must support students as they move towards independent thinking and problem solving by helping them develop essential skills and understandings.

> *ll students need science activities that let them construct and use scientific knowledge and skills in many real-world settings. These activities must actively engage the learner—both her hands and her mind—in scientific investigation and the creation of ideas.*

Using Instructional Objectives

The unit you're teaching should specify the instructional objectives you want your students to master—the activities you want them to learn to perform proficiently, such as "explain how things burn" or "develop and conduct research on questions about food and diets." Each of your unit's objectives should be directly related to one or more Michigan Objectives/Benchmarks (see pp. 5-8).

Once objectives are determined, the next question should be "How will students demonstrate their mastery of this objective?" Given the objective above on burning, you may want your students to be able to explain why they should wrap in a blanket a person whose clothes are on fire, or predict the effect of wind on a burning forest fire, or perhaps explain how an internal combustion engine works. Thinking about the ways in which students should be able to explain and apply their understanding and show what they can do after instruction can help teachers choose instructional activities and strategies that will lead to desired outcomes.

Choosing Instructional Activities

The next question is, "What experiences will students need in order to eventually demonstrate mastery of the objectives?" These experiences—also referred to as instructional activities, or tasks—include not only lab investigations and projects where students use materials and collect data, but ***all*** learning activities: reading, viewing or listening to sources of information; writing descriptions and drawing diagrams or observations; making predictions and explanations; creating plans and designs; debating and discussing. Given this long list of instructional activities, a class that just listens to lectures or reads from the textbook may not be adequately prepared to perform the objectives of the unit.

Hands-on science can be messy. Kids of all ages make messes when they freeze water, make clay models, test foods with chemicals, or make hot-air balloons. Not only that, but sometimes experiments don't work out the way you planned, which can be frustrating. But don't give up hands-on science because it's messy or sometimes hard. It really has an influence on students' interest and understanding of science.

Strategies

We know that effectively teaching a variety of learners requires a large toolbox of instructional strategies (see the box on p. 41). Teachers choose the most effective techniques by visualizing the desired outcome, analyzing the components of the task(s) facing the learners, and considering the learning styles and developmental levels of the students.

Although there are always options, some instructional choices lead to better student outcomes than others. "Hands-on" is a particularly important strategy. Students of all ages engage with topics more readily when they can work with materials, rather than just reading about the topic. Students generate more and better questions when they have real experiences on which to base their questions. Students remember concepts better that emerge from what they've done, rather than what's been told to them.

"Hands-on" is a particularly important strategy for secondary as well as elementary students. Although their level of academic skills may allow teachers to lecture constantly, older students often need a hands-on/minds-on approach to help them make sense of and apply the more abstract ideas of high school science.

"Hands-on" without "minds-on," however, is a terrible waste of time and money. Just doing activities does not guarantee that students will learn what they need to from the activity. Students need to think about what the data means, how they may be explained by theoretical concepts, and what the results of experiments imply. They need guidance in recording and explaining their work, and connecting it to the larger ideas of science. And they need practice in the skills of inquiry, investigation, problem solving and explaining.

Teaching Strategies

Strategy	Purpose	What the teacher might say
Lecture/note-taking	• communicate new information to students • synthesize information for students	"Matter is any solid, liquid or gas."
Teacher-led discussion	• focus on significant questions • bring out students' ideas • review	"What are the three states of matter?"
Hands-on labs	• students experience authentic science • student data collection • motivation • performance assessments • inquiry	"How can we find the variables which most affect melting time?"
Simulations	• students apply information & experiences to relevant topic • students experience discussion, disagreement, debate & resolution w/in class context • problem solving • motivation	"Now that we have collected data about the plume of contaminants, we will role-play a town meeting to propose an acceptable, affordable clean-up solution."
Writing Assignments	• summarize understandings (explanations) • develop detailed hypotheses • performance assessments	"Does the evidence support your conclusions? Explain why you think that."
Reading/note taking assignments	• students read new information • students synthesize information	"Before you read, preview the text, and write three questions that you think the text will answer."
Teacher generated questions	• application • student review • assessment	"Now can you explain why an ambulance siren sounds lower when it goes by you?"
Student generated questions	• inquiry • student review • application	"What would happen if I added more vinegar?"
Video, laser video disk (LVD), film	• application to new situation • new information • visual information • motivation	"As you watch the film, notice three ways of producing electricity."
Computer, CD-ROM, LVD simulations	• application • simulation • problem solving • motivation	"First we'll watch to find out the problem, then we'll use the clues to solve the mystery."
Reviews (Games, pairs, LVD, computer, etc.)	• review • motivation	"Today, we'll play Jeopardy to review for the quiz tomorrow."
Projects	• inquiry • new information • application • simulation • problem solving • data collection • motivation • performance assessments	"The challenge will be to design something that can keep water hottest over a given period of time."

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The "minds-on" side of science learning takes many forms. Group discussions and debate are important, as is individual writing with feedback from the teacher. There are many appropriate reasons for a teacher to lead the class: calling attention to significant topics, modeling techniques or finished products, explaining grading criteria, imparting new information, leading discussions or conducting reviews. But heavy reliance on one teaching method, whether it is lecturing or "messing around with materials," is not sufficient to help students master the complex skills and knowledge of science literacy.

Basic principles of effective science teaching, from which specific strategies are derived, are listed in the boxes on pp. 43-45. These basic principles are supported by research and by the ways that science is conducted in laboratories across the world.

The National Science Education Teaching Standards call for more emphasis on:

- *Understanding and responding to individual students' interests, strengths, experiences, and needs*
- *Focusing on student understanding and use of scientific inquiry*
- *continuously assessing student understanding*
- *Supporting a classroom community with cooperation, shared responsibility, and respect*
- *Working with other science teachers to enhance the science program*

Designing Units and Lessons

Good units have a coherent storyline, one that answers an important question or a series of smaller questions. Effective units are often based on a learning cycle, which takes students through several stages in learning science ideas and their applications (see p. 37). Each stage in the cycle often uses several different teaching strategies, to draw on the strengths of a variety of learners.

Well-designed lessons usually begin with a question or review to access prior learning or tune students into the current topic. It is often useful (and considerate) to explain why the lesson is significant, and what it will accomplish in the larger scheme of the unit. If there is a product that students will construct or a process they will use, the teacher should model it and give students many opportunities to practice it with and without the teacher's assistance. Within the lesson (or series of lessons) there should be checkpoints so that both the teacher and student can monitor student understanding.

Grouping

Certain techniques for grouping students can affect their performance. Lab pairs have been a long-standing feature of science classes. Cooperative groups can be useful in some situations. Some teachers have found that same-sex groups can foster skills in some students by establishing a safe and comfortable working environment for them. Heterogeneous groupings can provide tutoring or modeling or challenge for lower achieving students, and reinforcement for other students. Probably there is no single grouping arrangement that would be appropriate for the whole school year. Again, teachers must use their own judgment, along with the findings of educational researchers, to select the configurations that best help students achieve the desired outcomes.

Everyone Needs Science and Science Needs Everyone

We must strive to teach more science to more people. To do this, we will need a greater variety of tools. ***All*** students must feel welcome in the science tent. We can help everyone feel welcome by recognizing the scientific contributions of women, African-Americans, Hispanics, Native Americans and other under-represented peoples. We must fight our tendency to portray scientists solely as white men in white coats. Teachers, parents and counselors must send the message that science is a field for many, not counsel certain students to avoid science classes. Welcoming everyone means encouraging boys and girls to keep trying to solve problems, rather than rushing too quickly to help the girls. As teachers, we must be cheerleaders and motivators as well as holders of knowledge.

Project 2061's Suggestions for Good Science Instruction

Project 2061, a long-term science education reform effort of the American Association for the Advancement of Science, is concerned not only with what science literacy means, but how to teach for it. The following table, based on Chapter 13 of ***Science for All Americans*** (Rutherford and Ahlgren, 1990, Oxford University Press) contains suggestions for good science teaching that closely parallel and expand on the other ideas presented in this Guidebook.

Start with questions about nature.	Begin with questions about phenomena that are interesting and familiar to students. Encourage students to observe, collect, handle, describe, become puzzled by, ask questions about, and argue about the devices, organisms, materials, shapes and numbers in their environment.
Engage students actively.	Provide many and varied opportunities for collecting, sorting and cataloging; observing, note taking and sketching; interviewing; polling; surveying; using instruments such as microscopes, thermometers, and cameras; dissecting; measuring; counting; graphing; computing; planting; systematically observing; and so on.
Concentrate on the collection and use of evidence.	Provide students the freedom to judge the relevance and interpret the evidence of their scientific enterprise.
Provide historical perspectives.	Place scientific ideas within historical contexts so students understand that ideas change and evolve over time and that science influences and is influenced by historical events.
Insist on clear expression.	Provide opportunities for written and oral expression. Expression is necessary to communicate ideas, is the forum that real scientists use, and is a powerful vehicle for working out one's understanding.
Use a team approach.	Design projects which require collaborative participation. "Real" science is done in groups, and students learn the responsibilities of team work.
Do not separate knowing from finding out.	Help students develop appropriate methods for finding answers for various scientific problems. The nature of the problem should dictate the method of inquiry. The goal is for students to develop scientific knowledge as well as scientific habits of mind.
De-emphasize the memorization of technical vocabulary.	Provide opportunities for students to discover relationships between concepts and to use concepts to solve problems. Understanding, not memorization, is the goal of science instruction.

Four Standards for Teaching and Learning

Developing scientific literacy for all students requires a special kind of teaching, as described in the vision statement on pages 1-2. In this kind of teaching, students are exploring the natural world and developing their explanations of it, by experimenting, observing and describing, designing and building, debating with each other, doing projects and research, taking field trips, reading journals and non-fiction works, asking questions, offering explanations, and citing evidence. This kind of teaching has much in common with teaching mathematics, social studies, and English language arts. The following Standards for Teaching have been adopted by science as well as the other subject areas, as focal points for discussions about the nature of effective teaching.*

Standard 1: Higher-order thinking. Students should routinely use their powers of observation and their abilities to reason and solve problems as they learn and communicate important scientific ideas. They should have many opportunities to critically assess arguments and the fit of evidence, to draw conclusions and consider implications, to break things apart into their component pieces (analyze) as well as to see connections in diverse ideas (synthesize), to foresee difficulties and plan accordingly. They should routinely make and test predictions, gather, represent and use data, consider problems and alternative solutions, figure out how things work, design and build, imagine, and ask probing questions.

Higher order thinking of this kind is critical to deep and connected understanding. It challenges students to go beyond rote memorization, to actively engage themselves with the questions, problems and issues of science, and the ways in which scientists deal with those questions. Whenever students write, discuss, explain, inquire, and produce things, they should be challenged to use their entire repertoire of thinking abilities.

This is critical because the essential "activities" of scientific literacy are those that students will be expected to do outside of school: diagnosing, explaining and describing phenomena, applying knowledge, predicting and testing predictions, designing and constructing, reflecting on the merits of arguments, questioning, communicating, making connections, making decisions based on limited information, etc. These are all "higher order" ways in which we think and reason about the world around us.

Standard 2: Deep knowledge. The goal of teaching should be for students to understand scientific ideas deeply enough so they can talk about them in their own words, apply them to show how things work, use them to find answers to new questions, and see connections within them. Scientific ideas may be expressed in simple language, especially for younger learners, but the content of science—to be worth learning—must be important, fruitful, enlightening. Every scientific idea is highly embedded in a conceptual ecology of other ideas,

Developing this kind of understanding takes time. It does not happen for most students if teachers short-cut the learning process by simply telling the definitions of key concepts, or the algorithms for solving problems, or the facts associated with the phenomena being studied. Instead, students need to spend time looking closely at evidence, figuring out what it means, and arguing about various explanations. As they do this, they come to understand deeply the ideas behind the concepts, often before they have terms and definitions to apply to them. Then when they are given the terms and definitions, the meaning makes immediate sense to them because they have developed a deep conceptual understanding of the phenomena and systems they are studying.

It is understandable why many teachers tend to jump to the "punchline" of a topic—skipping over its applications and deep connections to simply list its terms and definitions: Often, that is all there is in textbooks, a shallow examination of a topic with few examples, just the facts and definitions. If the goal is simply to get through the entire textbook, and "cover" every topic, then students can't do much more than simply read each page and go on to the next chapter, memorizing (if they can) the terms and definitions. But this is a false, surface-level punchline. When the goal is to "uncover" the ideas, connections, and applications in the content, textbooks become only guides to the basic storyline. "The rest of the story" is presented by teachers (in discussions and activities as well as lectures) to develop a deep understanding of ideas and how they are used to explain the natural world.

Unfortunately, teaching for understanding is difficult. It demands more of students—more mental effort than listening to traditional lectures. And because teaching for understanding often reveals the ways in which science is not commonsense, it demands an openness to new ideas.

Standard 3: Connections to the world beyond the classroom. Learning should be related to young students' everyday lives, their neighborhoods and communities. As they get older, what students learn should be usable as they enter the larger world beyond their communities.

There are two good reasons for this. The first is science literacy, which requires that students learn how to understand and operate within the world around them. Because science literacy is essential, the problems and examples used in teaching should be about real events, real places, and real phenomena.

The second reason relates to motivation. Students must be interested in the ideas of science and see their relevance if they are to care enough to spend the time needed to understand scientific ideas and their applications.

Making connections to the world outside the classroom does not mean that instruction should be parochial, limited only to one's local community. Quite the opposite: Teaching should expand opportunities, open up new horizons, and acquaint students with the wider world beyond their own homes and experiences. Students should be immersed in the world as they learn all of their subjects, even though they usually spend most of their time in a classroom.

Standard 4: Substantive conversation. Students need to talk about the ideas we want them to learn, to debate what evidence means, and to ask probing questions. This is both a mark of their mental engagement with the subject and a necessary teaching strategy for learning deep knowledge and how to use, construct, and reflect on it. When teachers ask questions, they should ask ones that draw out students' thinking, that make them refer to observations and other evidence, that make them take a stand and support it. They should ask "Why do you think that?" and "How do you know?"

While substantive discussion is becoming more the norm in science classes (as opposed to lecture and note-taking), it is important to recognize that teachers have a critical role to play in helping students develop scientific ideas. While teachers are often facilitators of students' exploration and cognitive coaches during students' construction of ideas, their role of introducing and explaining new concepts, showing how those new concepts can be used, and demonstrating how to perform new activities is central to the learning process. Only when new concepts are introduced and explained clearly by teachers can students practice how to use them effectively. But only when students are allowed to discuss and use new ideas, can they attain challenging standards of content.

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* These four standards, taken from the work of Newmann, Secada, and Whelage at the Wisconsin Center for Educational Research, are described in the Center's more generic terms in *Michigan Curriculum Framework*, available from Michigan Department of Education. The *Science Education Guidebook* lists these principles here, rewritten in the context of science teaching and learning, as an aid to elementary, middle and high school teachers trying to find connections among the teaching of core academic subject matter areas.

Vignette: Teaching for Science Literacy

The vignette on these pages illustrates in some ways the Standards for Teaching and Learning on the preceding pages. Notes in the margin help explain how each Standard can be seen in the vignette.

Represented in the vignette is the heart of teaching—the interactions between teacher, students, and activities. Much of the "behind the scenes" work of teaching is not represented, especially the planning, consultation and collaboration with other teachers, the after-class work with students and parents, the preparation for conducting class activities, and professional development. However, all of that work is central to teaching.

This vignette is a composite of real experiences in several classrooms. Names are fictitious. In it, students are working with a unit developed by Michigan teachers based on Content Standards and Benchmarks and designed to illustrate the goals for scientific literacy (see page 5). The unit is part of the *New Directions* series (see appendix for ordering information) and is used by teachers across the state, in classes that range from general science to high school biology to adult education. Many regional Mathematics and Science Centers provide workshops on this and other *New Directions* units.

Ninth graders in Mrs. Lapham's General Science class are studying a unit called Food, Energy and Growth. Last week they collected data on various foods by testing them in the chemistry lab to identify carbohydrates, proteins, and fats. The unit began with these chemical tests and would end several weeks later by having students design nutritious meals based on what they knew about the components of various foods.

Students investigate the natural world as an integral part of science learning. Investigations give them opportunities to use their powers of observation, their abilities to reason and solve problems, and to use tools that are appropriate to the inquiry. (Higher Order Thinking; Deep Knowledge; see also the "Constructing New Knowledge" Standard/Objectives)

Early in the unit, the students read in their text, "The three major components in food are carbohydrates (which include sugar and starch), fats and proteins." Then Mrs. Lapham asked the class, "Where have you heard of these before?"

"I've seen those on cereal boxes," offered Katrina.

"We talked about fats in health class," said Arnold. "The book said that too much fat is bad for you."

Mrs. Lapham asked, "Does anyone know why fat is not good in large amounts?"

"I think it has something to do with your heart," suggested Marie.

"Naw," Reggie countered. "They just tell you that about anything that tastes good."

The teacher checks students' prior knowledge, to design instruction based on what students know and that addresses their naive understandings. (Deep Knowledge)

Mrs. Lapham found that her students didn't know that carbohydrates, proteins, and fats are what actually make up food (along with fiber); they didn't know what carbohydrates and proteins are used for in our bodies. This information about her students' prior knowledge agreed with the results of research conducted by the unit developers and helped to guide her as she planned her lessons and interacted with students in class.

When they first began their food tests, they did not have a strong sense of how to conduct these types of experiments. Mrs. Lapham modelled the procedure and discussed with students the rationale behind it. She guided them in group interaction, making suggestions to facilitate group success.

Students freely ask questions as they pursue understanding. (See "Constructing" Standard/Objective)

Whole class discussion and debate is as typical as small group work; students listen to and respond to each other. (Substantive Conversation)

Craig was ready with a question when Mrs. Lapham got to table 4. "Why do we have to test water? It doesn't have any food in it."

"Craig, that's a good question. Let's see if anyone else was puzzled by that part of the procedure." Mrs. Lapham walked to the front of the room and wrote "Time Out" on the chalkboard. After about 20 seconds, the room quieted and the students turned toward Mrs. Lapham.

"Craig asked an important question about the food tests. I wonder if anyone else has the same question." She looked at Craig. "Please say your question again, Craig."

Craig repeated his question and the room erupted with assenting comments. "That's really stupid, Mrs. Lapham," agreed Teresa. "Why should we test something that's not even food?"

Mrs. Lapham turned to the whole class. "Did anyone notice a change in the indicator when it was mixed with water?"

"I did," volunteered Freya.

"What did you see?" asked Mrs. Lapham.

"The iodine solution changed from dark orange to light yellow."

"So what did we learn by testing water with iodine?"

Joel raised his hand. "We learned that the iodine will get lighter when you add water, but that's not the change you're looking for."

"That's right, Joel," agreed Mrs. Lapham. "When you tested other foods did you see any tubes that showed the same color change as the water?"

Tomas raised his hand.

"Yes, Tomas?" encouraged Mrs. Lapham.

"Test tube #5, with the cooking oil in it changed to light yellow, too," he described.

"What does that mean?" queried Mrs. Lapham.

Mark's hand shot up. "I've got it!" he cried. "There isn't any of the nutrient we're testing for in the cooking oil."

"You're right," smiled Mrs. Lapham. "The test tube with water in it shows us what the solution looks like when there is no reaction. Does anyone know what scientists call that part of the setup?"

"That's the 'control,' isn't it?" offered Bonnie.

"Yes," replied Mrs. Lapham. "It's an important part of experiment design."

"I get it, now," exclaimed Craig. "Without the water to compare to, we wouldn't know that the cooking oil change didn't really mean anything."

"Right, Craig," agreed Mrs. Lapham. "Who can tell me which nutrient iodine tests for?"

"Is it starch?" queried Kayli.

"Well," coached Mrs. Lapham. "What makes you say starch?"

Kayli said. "Test tube #2, the one with the corn starch solution, was the only one that changed to a different color. So, I think iodine reacts with starch."

"Which groups got the same result?" asked Mrs. Lapham of the class. Several students raised their hands.

Mrs. Lapham called on Al, who did not have his hand raised. "What result did you get?"

"I don't know," Al replied dully. Then he complained, "All the tubes changed color. I don't know how to tell which is the one to look at."

Mrs. Lapham explained about the "control" in test tube #1, and how to use that as a comparison.

"Oh, okay," said Al. "I see now. Test tube #2 is definitely different."

"Continue your tests, now," directed Mrs. Lapham. "You have about ten more minutes until clean up time. I'll give you the signal."

Later, as Mrs. Lapham passed table 7, she spoke to Al. "Why do you think we're testing foods that are light colored?"

"I don't know," intoned Al. Then he thought for a moment. "The iodine is pretty dark, so I guess it might be hard to see the color change in a Coke."

"Exactly," laughed Mrs. Lapham.

The teacher checks students' developing understanding often, keeping notes of students' progress both for coaching and for conferences with parents.

During the second food test, Mrs. Lapham answered questions about the procedure and corrected problems as they occurred. She gave the students additional suggestions about group interactions.

Initially, students were resistant to working in small groups. The third day of the unit, the whole class ground to a halt.

Mrs. Lapham got the class' attention. "I think we're having a problem functioning effectively in groups. These are real problems. These food tests are a lot easier to complete when everyone does part of the work. Let's make sure each person has a role and knows what to do. If you don't remember what the roles are, check the overhead. If your group can't figure out how to do the tasks from your book, raise your hands and I'll come help you."

Group work is the norm. Students of both genders and all ethnicities share key roles in groups.

Several hands went up at table 2. Mrs. Lapham sat down with the students.

"Mrs. Lapham, these results are confusing," complained Carla.

"Yeah," agreed Marie. "We're getting all different colors."

"Let's look at your 'control' test tube results," directed Mrs. Lapham. "What color change did you see there?"

"It changed from dark blue to light blue," stated Tomas.

"What does that tell us?" prompted Mrs. Lapham.

To develop science literacy, students should explore the natural world and develop explanations of it, by

- *experimenting,*
- *observing and describing,*
- *designing and building,*
- *debating with each other,*
- *doing projects and research,*
- *taking field trips,*
- *reading journals and non-fiction works,*
- *asking questions,*
- *offering explanations, and*
- *citing evidence.*

"That the Benedict's solution will change to lighter blue when you add something it doesn't react with," explained Tomas. "We know that from what we learned in the first food test."

"But I still don't get it," Carla said. "Some of the other tubes turned light blue, but then we got all different colors."

Patiently, Mrs. Lapham helped the students focus their attention. "Let's look at your observation chart. Which of the basic test substances caused the Benedict's solution to turn light blue?"

Marie read from the chart. "Corn starch solution, gelatin solution, and cooking oil all changed to light blue."

"And what color did you see in the remaining tube?" Mrs. Lapham prompted.

"It turned orangey-red," reported Carla.

"And what substance were you testing?" Mrs. Lapham asked.

"Glucose solution," Marie stated.

"What is glucose?" probed Mrs. Lapham.

"It's a kind of sugar, isn't it?" suggested Marie.

"Right," confirmed Mrs. Lapham. "So, what nutrient does Benedict's solution react with?"

"Sugar!" responded Arnold enthusiastically.

"Does this make sense so far?" Mrs. Lapham checked all faces for assent. "Now, which other substances you tested showed light blue?"

"Only the cooked egg white," answered Tomas.

"What does that tell you?"

"That egg white has no sugar in it."

A light seemed to go on inside Freya. "Does that mean that any other color indicated sugar?"

"Exactly, Freya," Mrs. Lapham turned to Marie and Carla. "Does that make your results easier to understand?" They both nodded.

"Awesome," marvelled Arnold. "Everything else had sugar in it!"

"So, all the other colors mean sugar?" surmised Carla.

"Yeah, red, brown and even green?" asked Marie.

"You've got it," Mrs. Lapham smiled.

As the students' familiarity with the nutrient testing procedures increased, the problems subsided. After the students tested the foods Mrs. Lapham brought in, including peanut butter, cold cereal, milk, crackers, and hamburger, Josiah asked, "What about cookies? What would happen if we tested them?"

Rudy spoke up, "How about macaroni and cheese?"

"Or hot dogs?" offered Alicia. The room buzzed with suggestions.

Mrs. Lapham raised her hand. "May I speak?"

"Sure, Mrs. Lapham," laughed Reggie.

Everyone laughed, including Mrs. Lapham. "If you have a food you'd like to test, bring it in tomorrow. We'll add that data to what we have collected so far," suggested Mrs. Lapham.

"Awesome. I'm bringin' in bologna. My mom says it's loaded with fat, but I don't believe her," Arnold told Freya.

During the third food test, Mrs. Lapham allowed her students to develop their own procedure. She listened to their discussions, focusing her attention on crucial aspects such as use of a control. She assisted each group of students in their efforts to cooperate with each other.

Responsibility for performance of key skills and habits of mind is gradually released to students. (Higher Order Thinking)

Working this way was new to many of her students. Some didn't like it at first—it seemed too hard and they didn't know exactly what to expect. They were used to "the bargain"—the tacit agreement between some students and some teachers that says "I'll behave myself if you don't push me too hard." Making these kinds of changes in her teaching required some new approaches to classroom management, some "heart-to-heart" talks with students about why this new way of learning was important, and some additional modeling and structuring of class activities.

Mrs. Lapham slowly cruised the room, listening to the students' conversations, watching their faces. Her presence was noticed by the students and helped some of them stay on task. Most of them, however, simply ignored her unless they had a problem their group could not solve. Mrs. Lapham stood next to table 6, listening to the conversation at table 7.

"We're supposed to work this out as a group," said Janine.

"I don't think it will be too hard," suggested Josiah. "We just use the same basic procedure as in the second food test."

"Except we don't have to heat it," Kayli reminded them.

"Right," agreed Ken.

"That was not necessary," Janine defended her friend.

Mrs. Lapham stepped up to table 7. "Josiah, how about if you write out the first step of the procedure. Then you can pass the sheet around the table, with each of you writing one step."

"Good idea," encouraged Al. They went to work. Mrs. Lapham relaxed and moved on.

At table 4, Craig and Mark were discussing the setup.

"There are four test substances, so we need four test tubes," Mark stated.

"I think we need five," suggested Craig.

"Why?" Mark challenged.

" Remember, we need one for the water — you know, the 'control,'" explained Craig calmly.

"Oh, yeah," recalled Mark, relaxing. "We have to know what it looks like when no reaction takes place."

Mrs. Lapham continued around the room and overheard this discussion at table 2.

"This one is pink and this one is violet," said Carla in a surprised voice.

"I think we should compare the foods to the control, not to each other," Tomas reminded her.

"Oh, yeah, okay," agreed Carla. "But why are there so many different colors in these reactions?"

"Maybe there are different kinds of proteins," suggested Freya.

"Awesome," exclaimed Arnold. "Look, these two are pink, and this one is violet. Do you think that means that egg white and cottage cheese are more alike than peanuts and egg white?"

"Mrs. Lapham, is that true?" asked Marie.

"I think we would need to run a few more tests to be sure of the relationship. But that would be a good hypothesis to test. Would you like to try it?" encouraged Mrs. Lapham.

"Nah, we'll just stick to these tests for now," decided Arnold.

"So, wait a minute, are these all positive tests for protein — the pink, purple and violet?" asked Carla.

"They're all different than the control, aren't they?" coached Tomas.

"Yeah," admitted Carla. "So, I guess all of them contain protein."

"Hooray," cheered Mrs. Lapham silently and continued cruising.

Multiple means of displaying information are used, not just the chalkboard. Computer technology is used when appropriate.

Students evaluate the strengths and weaknesses of claims, arguments, or data. (Substantive Conversation; Benchmark/Objective 2.5)

As the experiments progressed, each group recorded its results on large posters around the room, making long lists of foods that contained fats, proteins, sugars and starches. The lists would be used throughout the unit, as a way of bringing students' attention back to specific foods.

While they were spending their class time conducting these experiments, students had the assignment of bringing in food labels and magazine advertisements containing information and claims about health products, vitamins, diet programs, and foods. They used the labels to analyze more complex foods and construct healthy menus, and they discussed and critiqued the claims made in the ads.

The questions posed by the teacher and by the curriculum materials are essential questions for understanding the importance and depth of the discipline, and allow for the development of higher order thinking. Real-world examples, applications, and career contexts are used often—in this case, ones that relate to biotechnology. (Deep Knowledge; Higher Order Thinking; Connections to the World)

As the unit continued, the class explored what happens to food after it enters their bodies. The questions for this part of the unit were: Where does food go after you swallow it? and How is food used by your body for energy and growth? They started by drawing pictures of the path they thought food follows as it goes through their bodies, and writing explanations of what happens to it along the way.

Most of their initial pictures showed parts of the digestive system: the throat and the stomach, and in a few cases the intestines. Several showed where waste exits the body. Almost none showed any parts of the circulatory system—the blood vessels that carry digested food away from the intestine to every cell of the body.

Mrs. Lapham realized this was normal. The annotated teacher's guide for the unit contained notes about students' thinking, which prepared her for typical responses. She read in the guide that while most students know from everyday learning that food gets digested, they do not know that digested food has to go to every cell in the body to be used for energy and growth. Based on the research the unit developers cited, she was not surprised when her students did not include the circulatory system in this initial drawing, but she knew that her task was to get them to understand that food does not just go to the stomach, get digested and somehow "used," and then exit the body as waste. She knew that she had to get them to connect the processes of the digestive system with the processes of the circulatory system, and perhaps even more difficult, to help them understand the biochemical processes that take place in each cell.

Students communicate their findings and express their ideas in a variety of ways, including drawing, writing, and speaking. Alternatives to spoken and written descriptions are often used, including maps, diagrams, flow charts, cutaway views, computer models, etc. (Deep Knowledge; Higher Order Thinking; Connections to the World)

To accomplish this, she would use a combination of computer models, video footage of actual digestive system components, lab activities, simulations and library research to help students piece together a complete picture of how food is used in the body. In one of the lab activities, students investigated how our body's need for oxygen and food relates to our levels of exercising, by collecting data on the body's production of carbon dioxide during exercise. They used the data collected from this investigation to piece together an understanding of the chemical processes going on in our cells when food is used for energy.

Students learn from a variety of materials, not just the textbook.

Towards the end of the unit, students would use their new understanding to explain what happens when people gain and lose weight. They would actually calculate the weight gained and lost when people eat a meal, use the bathroom, exercise, and simply breathe. This extension activity would help them connect the diets they analyzed earlier with the actual effects of food in their bodies.

Students use mathematics appropriate to understanding the content. (Higher Order Thinking; Connections to the World)

At the end of the unit, Mrs. Lapham had students construct "healthy eating" posters to be displayed in the middle school. On the posters they were to draw again the path they think food travels after it is eaten, and write about what happens to food in their bodies. She would check their explanations for several key elements:

The teacher challenges each student to think deeply about content, to practice the skills they are learning, and to apply what they know to new problems. (Higher Order Thinking; Deep Knowledge; Connections to the World)

1) A complete understanding of the flow of food material through the digestive system (mouth, throat, stomach, small intestine) and circulatory system (blood vessels) to the cells (in every part of one's body), including an explanation of digestion. (Each food component is broken into smaller and less complex molecules—proteins into amino acids, fats into fatty acids, and carbohydrates into glucose, which can then pass from the digestive system into the circulatory system; see benchmark/objective SCI.III.4.9, Using Life Science Knowledge about the Organization of Living Things: Explain how selected systems and processes work together in plants and animals.)

Students use multiple means for demonstrating their understanding, not just paper-and-pencil tests. Student performance is judged by the teacher along several key criteria based on Benchmarks/Objectives

2) A chemical description of how digested food is used by cells for energy, including an explanation of the role of breathing in this process. (Cellular respiration is the chemical reaction of glucose [from food] with oxygen [from breathing]—both delivered to cells by the circulatory system; energy is released in this reaction, to power all cell functions, and the by-product of carbon dioxide is

carried away from the cells by the circulatory system to be released through breathing; see benchmark/objective SCI.III.3.4, Using Life Science Knowledge about Cells: Explain how cells use food as a source of energy.)

3) A description of how we grow by using the food we eat, and why it is important to eat certain foods. (Amino acids from protein-rich foods, along with vitamins and minerals from fruits and vegetables, are delivered to our cells by the circulatory system, then used as building blocks to make hundreds of different proteins, which are used to make the new cells that are added to our existing muscle, bone, and other tissue cells, resulting in growth and weight gain; see benchmarks/objectives SCI.III4.12 and SCI.III.3.6, Using Life Science Knowledge about the Organization of Living Things: Explain the process of food storage and food use in organisms; and Using Life Science Knowledge about Cells: Explain how multi-cellular organisms grow, based on how cells grow and reproduce.)

Teachers remediate as necessary (Deep Knowledge)

If their posters still contained naive ideas about digestion and food movement, or about oxygen use and carbon dioxide production, or how weight is gained or lost, she would find additional ways to help individual students come to understand these important ideas.

Supporting and Encouraging All Students

The information age will place great demands on our children. As young adults of the 21st century, they will find themselves in an increasingly complex and highly competitive technological, economic and social world. Scientific and industrial enterprises will need more scientists and engineers. Every business, every service will need workers who can effectively solve problems and make decisions in scientific and technological areas. Our society will need citizens who can make informed decisions as voters and consumers.

Because of this, *all* students will need to become literate in science, and *all* students should have the opportunity to pursue scientific and technological careers.

There are barriers, however, which restrain students, particularly females and minority students, from becoming scientifically literate or pursuing science careers. They show up in our curriculum, our teaching, and our counselling of students. For example, classroom teachers, counselors, and even parents have suggested to girls, either intentionally or unwittingly, that science is a field for boys; scientists are often depicted as white males, and that image affects the aspirations of our students; and many students with special learning needs have felt unwelcome and unable to cope in science classes where endless lecturing, note-taking, memorization, and narrow assessment criteria have not enabled them to show their abilities.

What can you do to encourage and support all students in science? Some suggestions are described here; others are available in the resources listed in the appendix.

Start by creating a high-quality science program for everyone. All students need a curriculum that is experiential, based on inquiry and problem-solving, which emphasizes understanding over content coverage.

Then examine your expectations for different groups of students (girls, boys, white students, African American students, Hispanic students, Native American students, students with special learning needs). Education is such an intensely human experience that the styles and behaviours of teachers are very influential. Expectations are conveyed through personal regard, classroom management practices, and questioning techniques. Pay close attention to the ways you interact with different groups of students. In many classes, boys are often encouraged to keep trying to solve problems on their own, while girls and special-needs students may be "helped" too quickly by being given answers. Boys are often given more opportunities to manipulate and experiment with tools, and to speak in class. Keep track of who gets called on, and whether they are asked challenging or simple questions. You and a peer might offer to do this for each other. Everyone should be allowed and encouraged to participate equitably in class activities. Have you created an atmosphere in your class where all students feel safe to ask questions or express an opinion? Every student should feel recognized and supported for their contributions.

Recognize that students have many different learning styles and needs. You may not be able to change the way a student learns best, so offer a variety of learning experiences that allow every student to develop their understanding. Many students have learning needs that will not be met by reading long textbook chapters or copying formulas from the board. These students need to measure a plant as it grows, hear the song of a whale, or construct a model of a molecule. In fact, probably most students need these kinds of hands-on activities to learn science well. Additionally, many students may have difficulty demonstrating their understanding via traditional assessment tools, such as written tests. Can they build you a model, or create a poster, or make a video that will demonstrate what they have learned? Hold learning targets steady for all students. Make each target explicit before beginning lessons and assessments. Permit the time each student needs to vary, rather than the number of students who achieve. Encourage all students to learn in the way that is best for them, and recognize that all learning styles are equally valid.

At the secondary level, give all students access to courses with high quality content, regardless of future career aspirations or past educational experience. All students need classes where scientific ideas are debated, tested, and used everyday in real-world contexts, to become literate in science. High school tracking policies that keep students out of high-quality science classes because they are not "college-bound" need to be examined carefully. Classes that focus on "lab skills" or "remedial vocabulary building" and lack important content are not suitable for helping students develop science literacy.

For all students to become scientifically literate, districts must be committed to providing everyone opportunities to do hands-on/minds-on science; to talk about science with each other; to ask questions and get timely answers; to use what they are learning in real-world settings; to reflect on how they know what they do; and to use language appropriate to their own experiences. Teachers have to recognize—to believe—that all students bring learning assets of one kind or another to the class.

Help *all* students reach high standards of learning

- Communicate to each student their unique worth and that they are capable of achieving at their highest potential;
- Create a learning environment characterized by openness, creativity and freedom, that encourages students to think analytically and critically;
- Utilize classroom strategies that stimulate interaction and dialogue, to promote learning as an active process of inquiring;
- Select activities that are built on real experiences and meanings from students' own lives;
- Create a physical classroom environment which invokes positive images of ethnic groups and provides multicultural resources to enhance instruction;
- Provide field trips and laboratory experiences that extend science and multicultural studies beyond the classroom;
- Enable students to successfully and confidently express—through projects, debates, and writing—their understanding and abilities;
- Provide activities for parents to become partners in the education of their children.

Also, give educationally-disadvantaged students the help they need to succeed. This help can come directly from teachers, peer "coaches," frequent mastery-learning assessment, or other special assistance. Many teachers find their greatest rewards in helping those students who don't always get the support or encouragement they need to succeed.

Giving all students adequate opportunities to learn does not necessarily guarantee strong learning. Results depend on what students put into their work, as well as the opportunities that teachers and schools give them. As part of your efforts to increase the science literacy and science opportunities of all students, encourage each one to make a strong, personal investment in understanding and encourage parents to support this personal investment. The combination of high expectations, personal regard and support, and an appropriate curriculum for science literacy will help many more students prepare for the challenges of the next century.

and culturally relevant teaching materials that emphasize the impact of women, cultures, and different ethnic groups on science and technology. Everyone should have the opportunity to see that science is a multicultural endeavor. Everyone should be able to take pride in their heritage and gender, and know that they, too, can contribute to science.’

What can you do?

What can you and your colleagues do to help everyone teach for scientific literacy? What changes would you need to make to bring the kind of teaching described in these guidelines into your school's classrooms?

SECTION 5

CLASSROOM ASSESSMENT

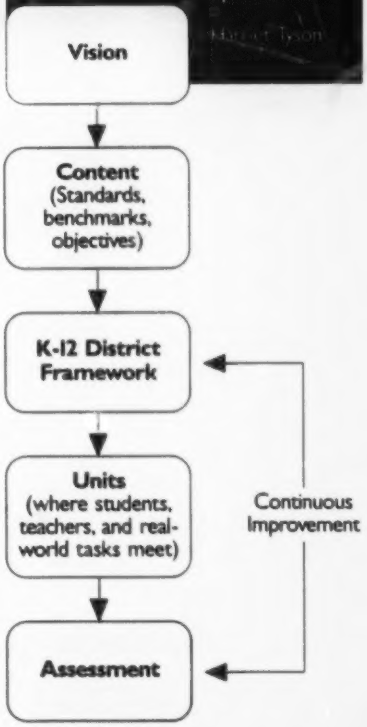
Assessment serves important purposes in teaching: It gives us diagnostic information about the curriculum, the pace of teaching, and our students' progress. It helps us know when the curriculum needs to be reexamined, how well we're doing as teachers, and how well each individual student is doing as a learner.

Although we've typically used assessments only to give students (and parents) some notion of their standing among peers, assessments can do much more. They can give students a notion of how they stand relative to the *standards* we hold up for their learning—that is, are students learning what we consider important, not just better or worse than the student sitting next to them, but well enough to be literate in science. This is important information for teachers, as well. Assessments can tell teachers what concepts or skills are especially difficult or confusing for students; teachers can adjust their curriculum or teaching to help students through these difficult areas.

But assessments have to be up to this task. If science programs were designed solely to acquire a body of facts, then traditional multiple-choice testing might suffice for determining what students know about science. But learning science is much more than acquiring abstract and unrelated facts. Students are now solving problems and analyzing complex experiment results. Students are accessing information and applying it to real-world problems, constructing and reflecting on scientific knowledge. Assessments in science must keep up with these changes in curriculum and instruction. New assessments must target scientific reasoning and depth of understanding, and provide multiple opportunities for students to demonstrate what they know and are able to do. New assessments can then provide students and parents with adequate views of students' performance and depth of knowledge.

Classroom assessment practices must enhance students' learning. Students should get feedback from assessments, and be given enough time and support to use that feedback to improve their own learning. This means that assessment results have to be more complex than just a single score or grade, which tells students and teachers nothing but a student's rank or placement on an arbitrary

> *"The yardstick is whether the children... can understand as well as memorize, apply as well as state, imagine as well as copy, solve problems rather than shrug them off, and make themselves felt in a society that seems to be in trouble for lack of these capacities."*
>
> Harriet Tyson


Vision
Content
(Standards, benchmarks, objectives)
K-12 District Framework
Units
(where students, teachers, and real-world tasks meet)
Assessment
Continuous Improvement

scale. Assessment results have to tell students and teachers about how well individuals and the class understand specific ideas and how well they can perform specific skills.

Assessments must give teachers useful feedback about instruction. Information about how students are understanding what we intend to teach is critical for planning. If a large number of students are not understanding what we teach, then perhaps the pace or the depth of teaching needs to change, or students need more practice. If only a few students are not understanding, then perhaps some kind of work can be set up to help them. But again, specific information about students' performance is needed, not just a letter grade.

Classroom assessments must be authentic. They must match the kinds of tasks that students are asked to do as part of instruction, and those tasks should match the kinds of activities that people do when they are using, constructing, and reflecting on scientific knowledge. In other words, assessment tasks (as well as instructional tasks) must have an element of the real world in them.

Assessment tasks should be interchangeable with good instructional activities. Not only does this ensure that assessments are authentic, but it allows all kinds of instructional activities to also be used as embedded assessment of student progress.

Here's an example of an authentic task: *Explain what the drops are that form on the outside of a cold water pipe in the summer. Explain 1. where they come from, 2. how they appear, and 3. how you might keep them from forming.*

This is much different from the traditional assessment question: *Which of the following is the change of state from a gas to a liquid:*

a. melting
b. condensing
c. freezing
d. evaporating

Match Assessments to Your Purpose

Assessment Approach	**Purpose**
Tests that are scored with letter grades or percents	To rank students relative to each other; to motivate students to work harder.
Tests that have scores listed by objective	To let students know how they stand relative to what's important to learn; to motivate students to learn more.
Tests with constructed-response items (such as short answers, explanations, essays, drawings), that teachers score with rubrics and provide written comments	To find out about what students think on a particular subject in order to diagnose particular conceptual learning difficulties; more time-consuming to grade, but more diagnostic than multiple-choice, matching, fill-in-the-blank items.
Oral questioning in class	(same as above)
Performances (like piano recitals, speeches or debates, designing and building useful things, conducting experiments using instruments and equipment, writing a letter), again scored with rubrics and written comments	To show what students can do in complex situations.
Projects	To show what students can do in complex situations given substantial time.
Portfolios	To store students' work over time, especially products such as written work, artistic creations, project reports, etc.; students decide what to store in their own portfolio, and should be involved in establishing criteria for evaluating progress over time.

BEST COPY AVAILABLE

School improvement should use achievement data from many sources. Too often schools only look at standardized achievement scores to judge their students' progress and the school's effectiveness. This is usually too narrow. School improvement and curriculum committees need to gather a wide variety of evaluation data before making decisions about spending resources and changing programs. And any school-wide tests that are used for decision-making must reflect what the school wants to teach, not just what the test developers put on their tests.

The new science MEAP and High School Proficiency Tests are taking steps forward toward more valid assessments of student knowledge. While not everything we want to know about students' knowledge and abilities can be learned from the MEAP and HSPT, they are good models for writing new classroom assessments.

What can you do?

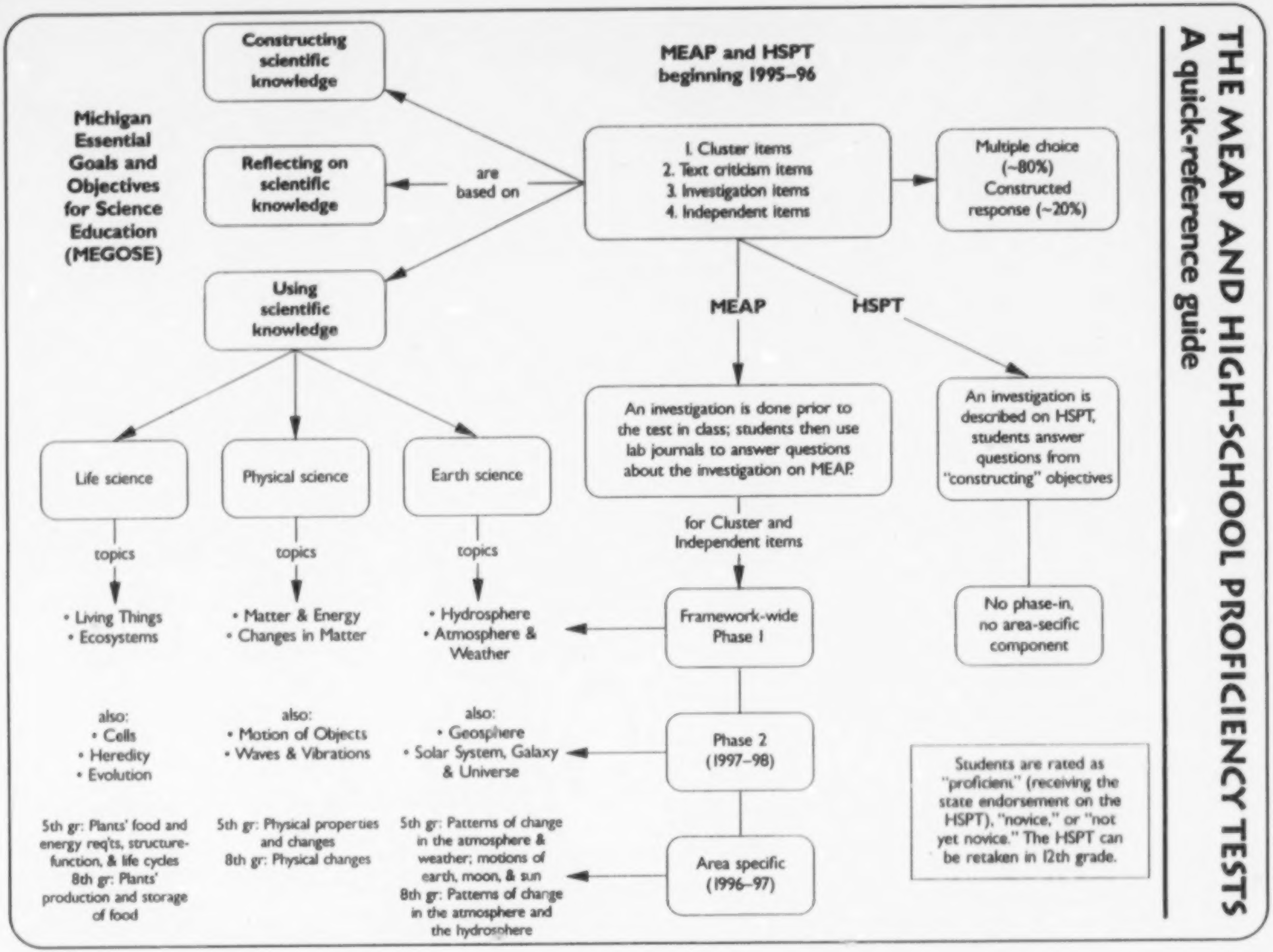
What can you do to learn more about your students' understanding, and give them better information about their developing science literacy?

Standards for authentic [illegible] assessment tasks:

1. Organization of Information [illegible]
2. Consideration of Alternatives [illegible]
3. Disciplinary Content [illegible]
4. Disciplinary Process [illegible]
5. Elaborated Written Communication [illegible]
6. Problem Connected to the World Beyond the Classroom [illegible]
7. Audience Beyond the School The task [illegible] students to communicate [illegible] knowledge, present a product [illegible] performance, or take some action for [illegible] audience beyond the teacher [illegible] classroom and school building.

To learn more about the MEAP and HSPT, and for more information about classroom assessment practices, see the resource section and *The Michigan Curriculum Framework.*

THE MEAP AND HIGH-SCHOOL PROFICIENCY TESTS
A quick-reference guide


MEAP and HSPT beginning 1995–96
Michigan Essential Goals and Objectives for Science Education (MEGOSE)
Constructing scientific knowledge
Reflecting on scientific knowledge
Using scientific knowledge
are based on
1. Cluster items
2. Text criticism items
3. Investigation items
4. Independent items
Multiple choice (~80%)
Constructed response (~20%)
MEAP
HSPT
An investigation is done prior to the test in class; students then use lab journals to answer questions about the investigation on MEAP.
An investigation is described on HSPT, students answer questions from "constructing" objectives
for Cluster and Independent items
No phase-in, no area-secific component
Life science
Physical science
Earth science
topics
topics
topics
• Living Things
• Ecosystems
• Matter & Energy
• Changes in Matter
• Hydrosphere
• Atmosphere & Weather
Framework-wide Phase 1
also:
• Cells
• Heredity
• Evolution
also:
• Motion of Objects
• Waves & Vibrations
also:
• Geosphere
• Solar System, Galaxy & Universe
Phase 2 (1997–98)
5th gr: Plants' food and energy req'ts, structure-function, & life cycles
8th gr: Plants' production and storage of food
5th gr: Physical properties and changes
8th gr: Physical changes
5th gr: Patterns of change in the atmosphere & weather; motions of earth, moon, & sun
8th gr: Patterns of change in the atmosphere and the hydrosphere
Area specific (1996–97)

Students are rated as "proficient" (receiving the state endorsement on the HSPT), "novice," or "not yet novice." The HSPT can be retaken in 12th grade.

SECTION 6

PROFESSIONAL LEARNING

Now that your district has created a new K-12 curriculum and found new instructional materials, how can all teachers learn the content and develop the teaching strategies that work to teach the new curriculum effectively?

Professional development happens any time educators are learning—during school improvement planning and curriculum development activities, when we observe each others' teaching, and when we inquire into our own practice.

Michigan Standards for Professional Development, shown on p. 78, are intended to help educators design and evaluate professional learning activities.

One approach is to send them to the university or ISD for workshops, or bring in a speaker for an in-service day. Unfortunately, those traditional approaches to professional development are only mildly effective with many teachers. Why? Workshops and in-service days usually do not provide teachers with the long-term, school-based support they need to really master new content and practice new ways of teaching.

New approaches to professional development are being tried across the state that provide long-term, on-going support for teachers and allow teachers to learn from each other, as well as from experts. These new approaches expand the definition of professional development to include all occasions where teachers are learning—learning new content while creating new units, learning what students really know while trying new assessments, learning about their own and each other's goals and commitments while designing new curricula, learning environments or daily schedules.

These new approaches expand the ***power*** of professional development by making it more pervasive, more responsive to teachers' needs, more immediate, and more relevant. Here's how you can make it happen in your school:

Recognize and use the knowledge and experiences of your own faculty. The people you work with have learned a lot about teaching over the course of their careers. Create opportunities to talk together about teaching and learning. Share what you know about students and science, solve problems together, plan together and talk about your goals. School improvement planning, curriculum improvement, informal discussions about what works and what doesn't, all contain the seeds of new knowledge when teachers are open to learning. This is what being professional colleagues is all about: working together in a "learning" community. This kind of sharing takes practice, though, and a genuine respect for each others' experiences and ideas.

New Ways to Expand the Power of Professional Development

If you want to learn about new and effective teaching strategies...

- Meet with your colleagues to talk about your experiences and approaches, solve problems together, and learn from each other. These can be grade-level meetings, or subject-matter meetings; within a school, across a district, or across a county. You can focus on what you do in your own classrooms, or you can read and share ideas about important issues in science teaching, such as students' naive ideas, new assessment techniques, teaching/learning cycles, questioning techniques, project-based science, etc. Discussion groups like this often use videos of good teaching or written case studies to get their discussions going. Or take turns reporting to each other on their own teaching and projects.
- Videotape or audiotape yourself, then watch or listen when you're in a reflective mood. Keep a notebook handy to jot down ideas.
- Sit in each others' classes, watch what goes on, and use what you see to reflect on your own teaching.
- Team-teach. This gives you the opportunity to praise what's good about each other's teaching, and to ask for help when you want it.

If you want to learn how to teach new units or activities...

- Teach a new unit at the same time as other colleagues. Meet together to solve problems, ask questions of each other, share what works, and figure out new content.
- Find a new classroom activity in a journal or at MSTA or MDSTA, and try it in your classroom. Invite a colleague to observe, to give you feedback on how well it worked.

If you want to understand what your students' are really learning...

- Work together to learn how to design and score better assessments. Write them during collaborative planning time, try them out in class, and review them together. Talk about what the results mean for improving teaching.
- Interview students to discover what they know—not to assess them and give them grades, but to find out what they've learned from instruction and what they haven't, what they can do with their learning, and what they still need and want to learn.

If you want to learn how to teach new content at your grade level...

- Plan courses or units collaboratively, drawing on each other's best ideas. Debate what should be included, help each other learn the content, find instructional resources, write and administer new assessment items and discuss what their results mean for the unit plan. The course or unit will be more effective because two heads (or more) have worked on it, rather than just one.
- Take a workshop that focuses on units or projects for a given grade level. Make sure the workshop incorporates the elements described on pp. 65.

If you want to learn new content...

- Take field trips as a faculty group, to learn from scientists in the community. Visit observatories, crime labs, civil engineering firms, fisheries, etc.
- Work as an intern in a local industrial or university lab.
- Work with teachers in other science disciplines to make interdisciplinary links and develop good teaching activities based on those links.
- Work with a mathematics teacher to figure out how to teach the mathematics needed to do science, and how to use science contexts to learn math. Work with an English teacher to learn how to incorporate writing into science, and experiment with how writing can help your students learn science.
- Take a course. But make sure the course follows the guidelines for workshops and courses on pp. 65. Then teach what you've learned (you'll lose it if you don't use it.) If others on your staff have also taken the course (or are teaching the same topics), meet with them on a regular basis to discuss any questions that come up with the new content.

If you want to help new and inexperienced teachers...

- Share your skill with a favorite unit by becoming a peer coach or demonstration teacher for others.
- Mentor beginning teachers.

Collaborate on new projects. Collaboration among teachers is not always easy, because they have been isolated in their own classrooms for so long. But collaborative development of new units, new assessments, new schedules, etc. is a wonderful way to pool your intellectual resources, as well as learn from each other.

Find time for reflection on the effects of your teaching. Reflection is something that all professionals do naturally when given the time.

Get teachers to work in other professional roles. Provide teachers with chances to learn new things about science and teaching, to give them a break from their daily routines and a chance to interact with other professionals in new settings.

Why are these new ways of learning and growing as professional educators important? Because they build the capacity of ***schools*** to improve ***students'*** learning. In schools with strong professional communities—where the staff is committed to a shared purpose, where they collaborate regularly, and where the staff takes collective responsibility—student achievement rises across all levels of ability. ***Schools across Michigan that are using new approaches—and building new attitudes and capacities for professional development—are having success implementing new curricula and new teaching strategies.***

> *hen teachers have the time and opportunity to describe their own views about learning and teaching, to conduct research on their own teaching, and to compare, contrast, and revise their views, they come to understand the nature of exemplary science teaching.*
>
> National Science Education Standards, p. 67

Leadership from the principal

New approaches to professional development, however well-intentioned, will not take hold in schools and produce wide-ranging results without strong support from administrators. ***Leadership from the principal and other central figures is crucial to making on-going professional development a reality.*** Principals and other

CASE STUDY: TALKING IT OUT

The need for professional development

It was pouring rain one afternoon, when several students in Mr. Badders' class asked "Why do the windows rattle when it thunders?" He was lucky to have students who asked questions, although he encouraged their curiosity. Five years ago he would have just told them the answer. Now he helped them figure it out, by doing investigations into sound, waves, energy, air, and storms.

Inquiry teaching makes strong demands on teachers. Mr. Badders needed to know what kinds of questions to ask during investigations, what kind of data to collect and how to make use of it, how to manage 25 to 35 students doing this all at once, what content is needed to explain the results, how to authentically assess student learning, how to apply the learning cycle, how to determine the age appropriateness of inquiries and when to say "I don't know." His regular monthly discussion group—a place for dialog with other teachers—helped him think through many of these issues and problems.

From a talk by Bill Badders, Cleveland City Schools Teacher, at the National Academy of Sciences, February 5, 1996 school leaders must make professional learning a key piece of curriculum reform, not an option or an afterthought. They must ensure that it is not just for the highly-motivated, and not what happens just on in-service days. Professional development must become a central part of the profession of teaching.

School leaders must also find the right incentives to get ***everyone*** involved in professional development. They must provide the right amount of time and the right circumstances for adults to learn. They must be able to answer the teacher's question, "How will this help me?" by providing evidence and examples. They must model what it's like to be a lifelong learner, someone who is willing to keep up with changes in a profession and apply what has been learned.

rincipals must help change attitudes towards professional development. They must ensure that it is not just for the highly-motivated, and not just what happens during in-service days. It must become a central part of the profession of teaching, for all teachers.

Principals are also the direct link between classrooms and the larger school system. They must ensure that the resources needed to make changes in teaching and learning are available, and that teachers' voices are heard in making district-wide decisions that affect the classroom.

Time

The greatest stumbling block in curriculum reform is time. Teachers need ***time*** to plan, discuss, coach each other, assess students and their own teaching, collaborate, encourage each other and reflect. Teachers must spend time together as well as alone—not time with one eye on the study hall, or time in five-minute or even 20-minute snatches, but substantial blocks of uninterrupted professional time.

How can this be accomplished? Basically, there are three ways to "find time" for effective professional development over the long term: Change how time is used, change peoples' responsibilities, or add to the amount of time on the job.

While the first step is often to add time at the end of the teaching day, there are other ways to engage teachers in professional learning when their energy and motivation are high. Schools across Michigan and throughout the country have tried different approaches, and some have been very successful:

- At the Mohegan Elementary School in the Bronx, teachers piloting a new curriculum are scheduled for the same daily lunch period and a common preparation period immediately thereafter—giving them a total of 90 minutes of shared time daily.
- In Merritt Island, Florida, the Gardendale Elementary Magnet School has adopted a year-round calendar, with three-week intercessions between quarters. The intercessions permit concentrated, two- or three-day meetings for teachers' planning, for which participants receive compensatory time.
- In Kentucky, the State Board of Education sought legislative permission to convert five of the required instructional days into staff development time.

Get the Most Out of Opportunities Now Available

In-service opportunities available right now, from local universities and colleges, ISD's, regional Mathematics and Science Centers, consultants and others, have an important place in a complete plan for professional development. But they need to use effective teaching practices themselves. In the same way as learning science requires a sustained effort—based on real experiences, discussions of concepts, and practice applying theory to new situations—so does learning to teach effectively. Workshops and courses need to provide those kinds of learning experiences.

And when the workshop or course is over, schools need to step in to provide the on-going and long-term support necessary to help teachers implement what they learn in workshops. Schools need to provide resources and support for teachers' sustained efforts, including equipment & supplies, time to reflect on the effects of their new practices, colleagial interactions, encouragement to try new approaches, and whatever else is needed. This support must come from other teachers, as well as administrators and parents.

The following questions have been developed from the Michigan Standards for Professional Development, as shown in the *Michigan Curriculum Framework* and on p. 78 of this Guidebook.

Make workshops, courses, and speakers work harder for you.
Ask the following questions before you enroll:

Goals

- ✔ Will these professional development activities address needs that our faculty has identified for themselves (for new skills and methods, knowledge of science content, classroom management, assessment, etc.?)
- ✔ How does this workshop, course, or seminar fit with our long-range school improvement plan or our individual professional learning plans?
- ✔ Is this workshop based on the Michigan Essential Goals and Objectives for Science Education (MEGOSE) and other shared visions for student skills and abilities, content knowledge, and dispositions?
- ✔ Will this workshop lead to real change in my teaching, to measurable improvement in my students' learning, and to my own significant personal and professional growth?
- ✔ Does this workshop teach about science content using an inquiry approach, so I can experience the kind of teaching and learning I want for my students?

Approaches

- ✔ Does this workshop challenge us to think deeply, reflect on knowledge, articulate our understanding clearly, debate, make connections and otherwise use our minds well *as we expect of our students?*
- ✔ Are the science problems and questions addressed in this workshop tied to local issues and other aspects of the real world?
- ✔ Will the teaching approaches addressed in this workshop really meet the needs of our students?
- ✔ Does this workshop integrate learning about important content with learning how to teach the content?
- ✔ Does this workshop give us time to practice what they teach us? Does it provide time to discuss new ideas in depth, and time to apply theory to new situations?
- ✔ Does this workshop use and teach us how to use appropriate technology?
- ✔ Is this workshop based on research?

Follow-up

- ✔ Will this workshop allow us to send a team, including the principal? Will we have time to discuss together what we've learned, and to make plans to support each other after the workshop?
- ✔ Will this workshop provide feedback to us on the ways we change our teaching? Will there be coaching as we try new ways to teach? Will we be able to get together after a couple months and talk about the changes we're making? Will we be able to contact the workshop leader with questions as we try new practices in the weeks following the workshop?
- ✔ Will the workshop encourage networking, mutual support, and professional consultation among colleagues.
- ✔ How can we share what we've learned with others after the workshop? Will the workshop encourage networking, mutual support, and professional consultation among colleagues.

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- A Rhode Island superintendent lengthened the school day by 20 minutes for four days in order to dismiss students at noon on the fifth. He made Wednesdays teacher meeting days and persuaded local churches, scouts and other youth groups to hold their activities on Wednesday afternoons. A small group of faculty rotated supervision of the youngsters of working parents who were unable to make other arrangements. (Holt High School, south of Lansing, uses a similar approach to make time for joint staff planning, faculty research and problem-solving groups.)

> *When teachers are given new assignments, they MUST be given adequate time to prepare, adequate professional development to learn what they need to know, and an adequate support structure (such as a mentor) to help them through the first year.*

- At the Urban Academy in Manhattan, students participate in volunteer community service activities each Wednesday afternoon. With the help of a coordinator, each student has a semester-long assignment to provide some service in the community—for example, helping in a legislative office, a teenage treatment facility, or an animal rescue group. This arrangement gives Academy teachers the full afternoon on Wednesdays for meeting. Faculty meetings occur regularly during this time, and each features one or more issues for deliberation.
- At Brooklyn College Academy—an alternative high school—classes are scheduled daily from 7:30 to 3:30. Even though the early morning "0" period is limited to special classes, clubs and tutoring, the Academy finds that the State's requirement for instructional time can be met in four-and-one-half days. Thus, faculty meet every Monday from 12:45 to 2:30 one week and 12:45 to 3:10 the next. (These examples are taken from "Finding Time for Collaboration" by Mary Anne Raywid, in ***Educational Leadership,*** September, 1993.)

As part of your long-range plan for curriculum reform, you need to decide first how much time is needed, then seek the necessary strategies to find that time. Communicating a clear purpose for this time, and its potential effects on students' learning, will help your community support the changes you propose.

For more information on professional development, see the resource section.

CASE STUDY: WEST OTTAWA

Moving from curriculum reform to improved teaching and learning

West Ottawa, a mid-size suburban school district in Southwest Michigan, is developing the knowledge and abilities of its teachers at the same time that it is creating and implementing a new standards-based science curriculum.

Their science renewal efforts began several years ago with district-wide meetings to develop a vision for science education. These meetings generated tremendous community support for school improvement, and led to the establishment of working groups of elementary, middle, and high school teachers. The working groups created a six week "summer institute" to inform themselves (and other interested teachers) about the *Michigan Essential Goals and Objectives* and other reform efforts in science, and used a portion of their time to study and create various approaches to their curriculum. It provided them with critical knowledge about goals, objectives, and strategies on which they could build and defend their curriculum. It provided them with new insight into how students learn. They were learning together, and teaching each other. Although they listened to outside experts when they needed to get specific knowledge and background on existing programs, they spent most of their time working through what they read and heard and applying it to their own district's needs.

At the elementary level, the district administration released a classroom teacher to head the team for the redesign of K-5 science instruction. The team, or cadre (as they began to call themselves) continued the development of a science curriculum that matched the needs of their students, and that adequately and appropriately addressed the state objectives for science education. They wrote and tested new teaching units that incorporated new instructional materials. The cadre's discussion and debate was far-ranging, from the overall shape and philosophy of their curriculum to effective teaching and learning strategies.

While they primarily were charged with producing a written document (the new curriculum), the cadre members were dedicated to bringing about far-ranging improvements in science teaching and learning. To do this, they knew that they had to bring all of the elementary teachers into this improvement effort, and help everyone understand and learn how to teach the new curriculum. One of the ways they did this was by demonstrating lessons to each other.

They also educated themselves on types of new assessment items, such as those used by the new MEAP and High School Proficiency Test, and wrote new assessments and rubrics for scoring them. As they tried out the new assessments across the district, they gained new insight into their students' knowledge and conceptual confusions. This insight was very helpful for continuing their curriculum work.

Being deliberate about their curriculum reform efforts, taking their time to debate and discuss and try out new things, paid dividends far beyond a new district curriculum. Their work was as much professional development as curriculum development: Everyone involved gained a deeper understanding of the content and teaching of science literacy.

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Planning for professional development

The next several pages contain tools that a district might use to create a professional development plan. This planning process begins with an assessment of needs related to curriculum, teaching and learning; continues with the identification or creation of professional learning opportunities; and concludes with an evaluation of how well the activities contributed to professional learning.

Professional development plans—for the district, each school, and every individual—are crucial for making a new curriculum come to life. Many districts prepare their professional development plans after they have established a new curriculum (see the section on Planning a Strong Science Program, pp. 9-14), in order to help all teachers understand the content of the new curriculum, learn how to use new teaching materials, discover what their students know and don't know about each topic, and ensure that all students learn from the new curriculum. Other districts begin planning for professional learning at the moment they begin planning a new curriculum. The choice is up to you. The steps that follow should be helpful regardless of where you are in the curriculum redesign process.

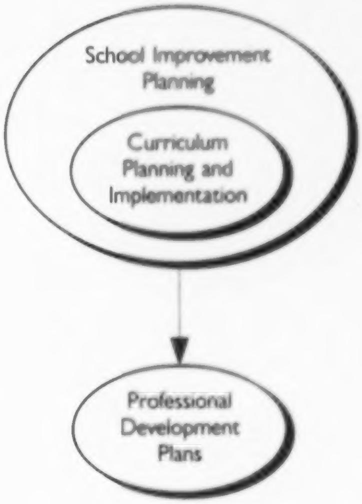
Convene a small organizing group of teachers and administrators. This group will shepherd the process through to its completion. They will be responsible for seeing that meeting agendas are carefully constructed to make the most of valuable time, for keeping the planning process on a positive and constructive note, for communicating between buildings in the district, for writing and distributing the professional development plans, and for advising others in the district and community about your work.

> *Just as effective and competent doctors and lawyers keep up with advances in their professions, teachers need to keep up with the latest in science and pedagogy if they truly want all of their students to succeed at high levels.*

This group should be composed of teachers and administrators who are credible in the eyes of the staff, who are positive leaders and good listeners. You might want to include at least one teacher from each building. Your district school improvement team may be willing to take these responsibilities.

Bring the entire faculty together to talk about improving science teaching and learning for all students, in all classes, beyond the creation of a new curriculum. These discussions are essential to establishing the tone for professional improvement, and provide the problems and issues that will be worked on over the next several years. You may need more than one of these discussions, and they need to be planned carefully to stay on a positive note.

Some districts find it convenient to hold several discussions of this type at different places, in schools, departments, as grade-level groups, etc., and then summarize the issues that emerge. Others use their school improvement meetings for this purpose—keeping in mind that districts are more effective at this stage of planning when they include the entire faculty. You will need a facilitator to lead your groups through these discussions, and to keep the discussions on a positive and forward-moving track—especially since these kinds of far-ranging brainstorming discussions can wind up focusing on external factors (such as the possibility of inadequate support at home), or factors that only the school board or district administrators can fix (such as pay, working conditions, and others); while those are real problems, they cannot generally be addressed by professional development. Also, if the need for curriculum improvement emerges from these meetings, you may want to use earlier sections of this Guidebook to facilitate curriculum planning and design.


School Improvement Planning
Curriculum Planning and Implementation
Professional Development Plans

These kinds of discussions often generate very difficult but important questions and concerns, such as:

- Some of us just got assigned to teach a new grade or a new subject, and we haven't dealt with the topics at these new grades or in these new courses.
- We try to use groups for doing activities, but they're hard to manage.
- We know there are students in our classes who are simply not engaged with science, but who could be if we had better ways of capturing their imagination or allowing them to show their capabilities. We just need to know what these better ways are.
- Students are supposed to do more writing on the MEAP and High School Proficiency Test, but they don't express themselves in writing very well now.
- We don't have enough time in our present schedule for real hands-on science.
- We're unhappy with the types of questions we ask on unit tests because we know they don't really allow students to show what they know.

Many schools find more success when an administrator is part of these discussions. Why? Because it often takes the leadership of the school principal, the department chair, a science specialist, or the curriculum director to bring together all the faculty, even those who are presently satisfied with their teaching (and their students' learning.) Once you have an administrator involved, get her or his commitment to remain involved throughout the entire process of planning and conducting professional development.

Teachers who have access to teacher networks, enriched professional roles, and collegial work feel more positive about staying in the profession.

Linda Darling-Hammond,
The quiet revolution:
Rethinking teacher
development. Educational
Leadership, p. 9, March 1996

Determine needs for professional development. Teachers usually make decisions about professional development based on perceived needs. They may need to know about new content when they have to teach a new grade or new course, or ways to use the new computer that's in their room, or how to manage activity-based classrooms, or how to deal with groups of students who don't seem to be succeeding. Many of these needs may have surfaced already in earlier discussions.

Using the questions listed below (or the self-assessment instrument provided in the resource section), along with feedback from parents and assessment data (including MEAP and HSPT), consider each teacher's need for greater knowledge or new skills. You may find that a discussion about needs works well with your group, or you may find that individual quiet reflection works best—or some combination of both.

Self-assessment of Needs for Professional Learning

Content

How well do I know the content I teach, its applications to the real world, and its connections to other ideas?

To what extent are real problems and relevant contexts part of my curriculum?

How familiar am I with the important questions, the salient metaphors and analogies, and the most significant tasks related to the topics I teach?

Do I have significant knowledge of students' misconceptions in the subject areas I teach?

Do I understand the Constructing New Knowledge and Reflecting on Scientific Knowledge objectives, and can I use them in my curriculum (i.e., integrate them appropriately with the science content)?

Teaching

What teaching strategies do I use? How well do they work to promote deep thinking?

How frequent and meaningful are inquiry-based activities in my classroom?

To what extent do I encourage students to ask meaningful questions and articulate their thinking?

To what extent am I able to scaffold students' developing understanding—to model and coach their performances, and turn over responsibility to them when appropriate?

How well do I integrate reading, writing, mathematics, and social studies into my science units? Can I help students learn to write better in science?

What do I know about how students learn that helps me teach? To what extent am I able to use the learning cycle as part of instruction? (See p. 37 for more on the learning cycle.)

How well do I use problems, issues, and deep questions to frame instruction?

To what extent do I use learning communities in my classroom?

To what extent am I able to use technology (e.g., computers, the Internet, CD-ROMs)?

How do I deal with different groups of students in my class (e.g., different ethnic groups, underachievers, overachievers)?

How well do I use community resources?

How well do I work with parents?

Assessment

Do the assessments I use give adequate feedback to students?

Do the assessments I use provide me with knowledge of individual students' developing understanding? Do I use this knowledge to guide my planning and teaching?

Summarize needs. The table below can be drawn on chart paper and used in a whole-group discussion to summarize needs for professional development—both individual's needs and the needs of an entire faculty. The facilitator should be prepared to relate the needs listed here to the issues generated earlier in this process, to assure a match to teachers' real concerns.

The needs generated here also should be viewed in relationship to the district school improvement plan. Many districts generate needs for professional development based on their school improvement goals. As long as those needs come from all teachers (not from the speculation of a single committee or administrator), and include science-related needs, they will lead to effective professional development.

Identified Needs in Professional Development

As a building (or department, or grade), our self-assessments show that our needs in each category below are:

For content understanding in areas tied to our curriculum and related to MEGOSE (see pp. 5-8):
1.
2.
3.

For teaching skills (e.g., how to pose engaging questions, how to manage and teach groups, how to conduct inquiry activities successfully, how to work with diverse learners, how to create learning communities, how to use technology, how to use new instructional materials):
1.
2.
3.

For understanding of how students learn, what they remember and what they forget:
1.
2.
3.

For assessment and grading:
1.
2.
3.

For issues related to restructuring, time, grouping, staffing, etc.:
1.
2.
3.

For interdisciplinary teaching and learning, (e.g., more writing in science, more connections to social studies, more units on new technologies, better integration with mathematics):
1.
2.
3.

For new approaches to working with underachieving students:
1.
2.
3.

Additional criteria for choosing and using professional development activities are available in the *Michigan Curriculum Framework* and the *National Science Education Standards*. See the resource section for ordering information.

Match professional development opportunities with the faculty's needs. You may start with a list of professional development workshops, speakers, courses, and other offerings available from your ISD, regional Mathematics and Science Center (see the resources section for a listing) or university. Keep in mind the set of questions regarding "good workshops" (pp. 65).

Their lists are only a beginning. They may not include the kinds of job-embedded, collegial learning situations described earlier in this section that can greatly strengthen your professional learning. You will have to examine those new approaches to professional learning and include ones in your plan that might meet your needs.

Needs	**Actions**	
	How can we meet our needs?	
What needs do we have as individuals and as a faculty?	*What do we know that's happening now? Use resource lists from your regional Mathematics and Science Center.*	*What else would we like to see happening beyond the activities listed at right (or to support those activities)?*
content understanding		
teaching skills and new instructional materials		
how students learn		
assessment approaches		
restructuring		
interdisciplinary teaching and learning		
working with underachieving students		

Writing the district, school and individual professional development plan. Once the professional development opportunities are listed, a detailed professional learning plan can be developed for the entire district, each school and each faculty member. The district plan can be drafted by the professional development organizing committee, with input from each school, and submitted for comments to the entire faculty.

Parts of sample district, school and individual plans are shown below. The key to writing useful plans is to show not only the activities in which each teacher will participate and the role he or she will play but also the expected gains from the activities. This provides the basis for evaluating the contribution of each activity to each person's professional learning.

The companion document, *Michigan Curriculum Framework*, contains a complete description of the state Standards for Professional Development and a discrepancy analysis tool for evaluating your entire professional development program.

LONGPOINT SCHOOL DISTRICT

District Professional Development Plan

1996–97, 1997–98

District School Improvement Goals Science	District Professional Development Concentration Areas—Science
1. Improve student's understanding of earth science across all grade levels.	1a. Improve teachers' understanding of state standards and benchmarks in earth science. 1b. Review existing earth science curriculum materials, replace or supplement as needed, educate teachers on implementation of new materials in keeping with state standards and benchmarks. 1c. Assess and revise as needed the earth science curriculum. 1d. Develop assessment expertise related to the earth science curriculum and MEAP/HSPT.
2. Improve students' abilities to construct new scientific knowledge and reflect on scientific knowledge, in the contexts of important community issues and personal concerns.	2a. . . . 2b. . . . 2c. . . .

SANDERS HIGH SCHOOL
Professional Development Plan
1996–97

To be created as a result of a planning process that takes the district school improvement goals and professional development priorities as a base, and assesses individual faculty's needs and desires for professional learning.

Activities	**Roles**	**Expected Outcomes**
1. Earth science and other interested science teachers will develop a collaboration with XYZ University geology, meteorology, and astronomy faculty to prepare and conduct awareness workshops on state science standards and benchmarks.	***Department chair*** will take the lead in planning an initial meeting, to include the ***curriculum director*** and ***all earth science staff.*** Awareness workshop dates, times, and leaders/facilitators will be selected. ***Department chair*** will coordinate the acquisition of needed materials, and prepare and distribute announcement to all appropriate elementary, middle, and high school staff and administrators.	Earth science teachers will become more knowledgeable of state standards and benchmarks as they plan and conduct workshops.
2. Monthly discussion groups will be held to examine curriculum materials, teaching methods, and classroom assessment tools.	***Don C.*** will attend facilitator training and lead the discussions; ***Meredith P.*** and ***Jackie M.*** will attend MSTA to find new teaching materials; ***Curriculum director*** will contact MDE for information on assessment tools. ***Department chair*** will establish meeting times and locations, and advise.	Faculty will use their knowledge of content standards and teaching principles to find effective instructional materials, design new teaching approaches and create new assessments. Using their knowledge will extend and solidify it.
3. Earth science faculty will observe teaching in others' classrooms or set up observations in model schools.	***Each faculty member*** will be both observer and observed; the role of the observer is not to comment on each others' teaching, but to reflect on their own.	New thoughts about teaching, ways of interacting with students, insight into what and how students learn.

Individual Professional Development Plan, 1996–97 **Teacher:** Don C.

Activities	**Expected Outcomes**
1. I will participate in monthly discussion groups with high school earth science staff and other interested teachers, as a colleague and as the facilitator.	1. ________
2. I will attend facilitator training sessions to learn to effectively facilitate faculty discussions.	2. ________
3. I will attend the MSTA annual conference to find new curriculum ideas and new instructional materials related to earth science, and share these ideas and materials with other members of the earth science discussion group.	3. ________
4. . . .	4. ________

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Make it happen. To make your plans happen, you'll need to find financial resources, time, and administrative support. Money for professional development in science is often available through state grants and other outside funding sources. Your Mathematics and Science Center may also have funds to support you.

Making new approaches to professional development work requires a good deal of resolve and flexibility. Call on your Mathematics and Science Center or ISD staff to help—they are often willing to share their expertise or act as outside facilitators (see the "open letter to resource providers" on pp. 76-77). You may also need to enlist support from your community for new school-based group learning plans, especially ones that require new uses of time during the school year.

Support each other as you practice the new things you learn. Be tolerant of each others' experimentation with new approaches. As everyone knows, change takes time and patience.

Evaluate your learning and plan new activities. Any single professional development activity is just a start on the road to new understandings and new abilities. Some professional development activities are more successful than others. Given this, take time to assess how much is gained from each professional development activity, and make changes to your professional development plans accordingly. Sit down as a group on a regular basis to reflect on whether your professional learning activities are taking you where you want to go.

Professional development programs should be firmly linked to national, state, and local reforms in curriculum, instruction, and assessment. The chief aim of professional development activities should be to help teachers and administrators improve the performance of all students.

Professional development activities should fulfill the need and desire of teachers to grow professionally throughout their careers. Teachers should be regarded and treated as lifelong learners.

Professional development should be an ongoing and integral part of school operations, not an add-on, piecemeal activity that occurs at the end of the day or solely on designated days.

Professional development activities should help educators overcome the isolation they experience and encourage networking, mutual support, and professional consultation among colleagues. On a regular basis teachers should be given time and opportunities to discuss teaching strategies and classroom issues with each other.

Professional development activities should be designed at the school building or district level in order to be responsive to the unique and varied needs of individual schools and communities.

Professional Development for Educators: A Priority for Reaching High Standards. Washington, DC: National Governor's Association, 1994

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An open letter to resource providers in the community

After identifying your staff's professional development needs, you might ask: "How can providers in our region help us meet our needs in professional development?" The following "open letter" contains some suggestions. You might simply send providers a copy of this Guidebook, with this page marked. Or you may want to write a personalized letter to the appropriate people in your region, outlining your needs and asking them to tell you how they could help. Use whatever applies from the list below, and add to your own list as appropriate.

Memorandum

To: Our Mathematics and Science Center, our ISD, higher education institutions, museums, nature centers, other providers of curricula and programs (such as DEQ, MUCC, MDE), science-oriented businesses and other resources in the community

From: Local school district science curriculum committee

Subject: Your help in implementing the suggestions of the Science Education Guidebook and the Michigan Essential Goals and Objectives for Science Education.

To get the most out of what we do, we need your help. Here are some ways that your work can support and move our work forward:

1. Because we base much of our curriculum work on the Michigan Essential Goals and Objectives for Science Education (MEGOSE), it would help us if you ***use MEGOSE*** to guide the topics and grade levels for which you provide curricula or programs.
2. We will make our ***scope & sequence guides*** available to you. Please use them to focus your programs and services.
3. Because many small districts don't have the resources to develop extensive curricula, you could convene all the districts within your service area to develop ***a shared curriculum guide*** (keeping in mind the in-depth topics for the 5th and 8th grade MEAP), with suggested instructional materials. Once a shared curriculum guide is established, you could provide the following services:
   - Workshops and other in-service opportunities on the ***suggested instructional materials*** within the shared curriculum guide, targeted at particular grade levels and topics. The instructional materials on which the workshops are based must be distributed as part of the workshop.
   - ***Kits of equipment and supplies*** that support selected instructional materials, to be sold or loaned and maintained on a yearly basis.

- ***Content-based workshops*** for teachers (for college credit, CEUs, district in-service requirements), tied to the shared curriculum guide.

4. We need ***in-service activities on specific topics*** such as science assessment, classroom management for activity-based science classes, and writing in science. Use the shared curriculum guide and MEGOSE documents to put these skills into the science context. Make sure these workshops meet our "standards" as listed on page 65.

   - Whenever you conduct in-service activities, ask us to help you ***set up ways of making our learning continue*** after the initial workshop has ended. This may be through on-going e-mail discussions, additional school-site meetings, or opportunities for us to share how we use what we learn.

5. You could help us prepare for the ***investigation problem*** on the 5th and 8th grade MEAP by developing a "practice" question or topic for inquiry, similar to the investigation problem. Publicize it for certain grade levels, and become the clearinghouse for different classes in the region to communicate their findings on this topic.

6. We need education and on-going support to use ***technology*** in teaching science. For example, introduce us to software that directly addresses MEGOSE objectives. Support us as we use the Internet. Model ways to use addresses on the Net that share one theme.

7. ***Become a clearinghouse*** for information on meetings, workshops and teleconferences. Use a data base to classify and contact teachers by grade levels or areas of interest.

8. We need to ***"network"*** across districts. To help us do this, you could sponsor special meetings for teachers by subject area, such as an "Earth Science" or "Biology" network. Many small districts have only one or two earth science or physics teachers. They might appreciate a chance to meet with others in the region, especially if the topics were relevant and engaging. Elementary teachers might find these subject-matter networks interesting, too.

9. Help us ***establish contacts with sites in our community*** where science is being done (e.g., university and industry laboratories, engineering firms, manufacturing plants, cooperative extension agencies), and help us to learn from the people who work there. We can understand how science is done and how it applies to everyday life. Help us arrange partnerships with business and industry people so that our students can learn about careers and community resources.

10. Make sure that all of your offerings engage us in inquiry, model new skills, give us immediate practice and feedback, draw on the best in relevant research and case studies, and provide time for reflection.

11. Help us to ***continuously evaluate*** what we're doing.

12. ***Work with other providers in the region to coordinate activities.*** That way, we'll have an easier time knowing where to look for help, and all of the resources of our region will be directed towards the same goals and based on the same vision.

13. ***Become facilitators of school improvement*** processes within our district. Show us new ways to improve what we do. Help us with professional development planning. Serve as a catalyst for the development of learning communities within our schools and districts, and across the region. Help us "break the mold" and do things in new and better ways.

Professional Development Definition and Standards
Michigan State Board of Education

The Michigan State Board of Education defines professional development as "a continuous process of improvement to promote high standards of academic achievement and responsible citizenship for all students. Professional development increases the capacity of all members of the learning community to pursue life long learning."

Standards for the *Context* of Professional Development

Quality professional development, structured and provided within a context of ongoing school improvement planning and a culture of collaboration, improves and sustains the capacity of the adult learner to:

Standard 1: understand and apply the elements of a market driven education system.

Standard 2: understand and apply systemic change principles and anticipate change as a dynamic process.

Standard 3: contribute to the plan and design of their own intellectually rigorous professional development.

Standard 4: increase personal level of involvement in implementing a continuously improving learning community.

Standard 5: use data on student academic achievement as the foundation for selecting professional growth alternatives.

Standards for the *Process* of Professional Development

Quality professional development, structured and provided within a context of ongoing school improvement planning and a culture of collaboration, improves and sustains the capacity of the adult learner to:

Standard 1: use inquiry and reflective practice within the learning community.

Standard 2: learn from recognized resources within both the public and private sectors, from successful models, and from colleagues and others in the learning community.

Standard 3: identify personal and adult learning needs and styles, and select appropriate modes of participation.

Standard 4: implement research-based leadership strategies to support and sustain ongoing developmental activities.

Standard 5: integrate technologies as tools to assist with the curriculum development, instructional management, and assessment practices.

Standard 6: invest time in an ongoing process of collegial dialogue, collaborative learning, and exploration of new and/or proven instructional strategies.

Standards for the *Content* of Professional Development

Quality professional development, structured and provided within a context of ongoing school improvement planning and a culture of collaboration, improves and sustains the capacity of the adult learner to:

Standard 1: demonstrate high learning expectations for all students.

Standard 2: demonstrate continuous improvement as a facilitator of student learning.

Standard 3: demonstrate continuous progress in developing the current content knowledge and its application, skill based, and instructional strategies required to facilitate effective learning for all students.

Standard 4: demonstrate knowledge and use of cross-disciplinary instruction and cross-disciplinary teams to facilitate student learning.

SECTION 7

RESOURCES

Books, Reports, Videos, Internet

Vision and Content

Michigan Essential Goals and Objectives for Science Education (MEGOSE) and the *Michigan Curriculum Framework* are available for a nominal cost from The Michigan Center for Career and Technical Education, Michigan State University, 133 E Erickson Hall, East Lansing, MI 48824-1034 (517) 353-4397 or (800) 292-1606.

Science For All Americans, Project 2061, American Association For The Advancement of Science. Rutherford, F. J. and Ahlgren, A. Oxford University Press, 200 Madison Ave., New York, NY 10010. (1991). (The basis for Michigan Essential Goals and Objectives/Content Standards and Benchmarks.)

Benchmarks for Science Literacy, Project 2061, American Association For The Advancement of Science, Oxford University Press. (1993).

National Science Education Standards, National Research Council. National Academy Press, 2101 Constitution Avenue, NW, Washington, DC 20418. (1996) (Standards for content, teaching, assessment, professional development, and science programs.)

Cultural and Gender Perspectives in Science, Culturally Relevant Material to Support Michigan's K-12 State Science Objectives. Michigan Department of Education, PO Box 30008, Lansing, MI 48909, 517-373-4223. $10.00 (1992)

Planning

Science Education Resource Guide. Developed by Gary Appel, MSSI (Michigan Statewide Systemic Initiative for Reform of Mathematics and Science), Michigan Department of Education, P.O. Box 30008, Lansing, MI 48909. Published by the W. K. Kellogg Foundation. Also available on MDEnet, at http://mde.state.mi.us. (A guide to resources available for science education improvement.)

How to Unravel Science Mysteries For Young Minds Without Unraveling: A Summary of Lessons Learned. W. K. Kellogg Foundation, One Michigan Avenue East, Battle Creek, MI 49017-4058. 616-968-1611. (1993).

Improving Schools from Within. Barth, Roland S., Jossey-Bass Publishers, 350 Sansome Street, San Francisco, CA 94104. (1991).

Pathways to School Improvement, an Internet service developed by North Central Regional Educational Laboratory (NCREL) and the Midwest Consortium for Mathematics and Science Education. Pathways contains information about school environment, students, content, educators, and teaching. Using a World Wide Web browser, find *Pathways* at http://www.ncrel.org/ncrel/sdrs/pathways.htm

SEMSplus modules

Excellent resources for all aspects of science education improvement. Available from the Seaborg Center, Northern Michigan University, 104 West Science Bldg, Marquette, MI 49855-5394 (Costs per module range from $2.50 to $4.50)

1. Science Curriculum Development: A Rationale for Change
2. Leadership and Accountability: Managing the Change Process
3. Science Education Research: Laying the Groundwork for Curriculum Reform
4. Reviewing the Science Program and Assessment of Needs
5. Present Trends & Future Directions for the Devel. of Science Curricula
6. Issues of Equity and Quality in Science Curriculum Development
7. Unit Planning for Conceptual Change
8. Curriculum Evaluation and Student Assessment
9. From Curriculum Committee to the Classroom
10. Curriculum Integration: A Multidisciplinary Approach to Science

Curriculum

Elementary School Science for the '90s. Loucks-Horsley, Kapitan, Carlson, Kuerbis, Clark, Melle, Sachse, Walton. ASCD (Association for Supervision and Curriculum Development), Alexandria, VA (1990).

Starting Again in the Middle School: The Importance of Strengthening Michigan's Middle-Grades Schools. Michigan League for Human Services. Available from W. K. Kellogg Foundation, P.O. Box 550, Battle Creek, MI 49016-0550. 800/819-9997.

The Way We Were…The Way We Can Be: A Vision For The Middle School. Susan Kovalik & Associates, Books for Educators, PO Box 20525, Village of Oak Creek, AR 86341, 602-284-2389, (1993).

Kovalik, Susan J. and Olsen, Karen D. (1991). *Kid's Eye View of Science: A Teacher's Handbook for Implementing an Integrated Thematic Approach to Teaching Science, K-6.* Village of Oak Creek, AZ: Susan J. Kovalik and Karen D. Olsen.

Available from NCREL (North Central Regional Educational Laboratory) and the Midwest Consortium for Mathematics and Science Education, 1900 Spring Rd., Suite 300, Oak Brook, IL 60521-1480. 800-356-2735.

- *Best Practices*, a quarterly newspaper of current projects, approaches, and materials.
- *Children As Explorers*, a one-hour videotape and guidebook showing how ideas can thrive and take root when students work out the complex relationships between science and their personal knowledge.

Publications from The National Center for Improving Science Education, 300 Brickstone Sq. Suite 950, Andover, MA 01810, 508-470-0098.

- *The High Stakes of High School Science.*
- *Science and Technology Education For the Middle Years. Frameworks For Curriculum and Instruction.* Bybee, Buchwald, Crissman, Heil, Kuerbis, Matsumoto, McInerney, (1990).
- *Science and Technology Education for the Elementary Years: Frameworks for Curriculum and Instruction.* Bybee, Buchwald, Crissman, Heil, Kuerbis, Matsumoto, McInerney, (1989).

Teaching and Learning

Ed Talk: What We Know About Science Teaching and Learning. Nancy Kober, Council for Educational Development and Research, 2000 L. Street, NW Suite 601, Washington D.C. 20036, 202/223-1593, (1991).

Why Do These Kids Love School? A video about classroom practices, distributed by Pyramid Film & Video, Box 1048, Santa Monica, CA 90406-1048, 213-828-7577, (1989).

Lifting the Barriers: 600 Strategies that REALLY WORK to Increase Girls' Participation in Science, Mathematics and Computers. Jo Sanders Publications, PO Box 483, Port Washington, NY 11050, 212-642-2672, (1994).

Equity in the Reform of Mathematics and Science Education. Southwest Educational Development Laboratory, 211 E. 7th St., Austin, TX 78701-3281. (512) 476-6861.

Videos

Michigan Gateways: 30 minute video magazines on mathematics and science education. Available from Michigan State University, 212 Communication Arts,

East Lansing, Michigan 48824-1212. (517) 355-2300 ext 422. See their web page at http://web.msu.edu/comptech/gateways/. Some titles include:
#103, "Diversity in the Classroom"
#104, "What Works: Tools for Teachers"
#105, "Transforming Oneself as a Teacher"
#204, "Tracking and Untracking"
#205, "Big Ideas in the Curriculum"
#206, "Active Learning"
#209, "Student Models and Misconceptions"
#301, "Do Our Classrooms Look Like This?"
#303, "Writing in Math and Science"
#306, "Orchestrating Discourse"

Science Images: Visions of Effective Science Instruction. Annenburg/CPB Math and Science Collection and North Central Regional Educational Laboratory (NCREL). Available from NCREL, 1900 Spring Rd., Suite 300, Oak Brook, IL 60521-1480. 800-356-2735. (A visual library for improving science instruction, with Facilitator's Guide, Viewer's Guide, and leadership Team Guide.)

A Private Universe: The original video; and *Private Universe Teacher Workshops* video series, Harvard University, 800/965-7373, part of the Annenburg/CPB Math and Science Collection. (The original video shows the difficulty of teaching science when persistent misconceptions are present. The video series includes shows on biology, chemistry, physics, environmental science and other aspects of teaching.)

Compendiums of resource materials

- *Mathematics, Science & Technology Education Programs that Work.* National Diffusion Network, U.S. Department of Education, Office of Educational Research and Improvement, Washington D.C. 20208-5645, (1994).
- *Promising Practices in Mathematics & Science Education: A Collection of Promising Educational Programs & Practices from the Laboratory Network Program.* U.S. Department of Education, Office of Educational Research and Improvement, Government Printing, 202-783-3238 or 202-512-1800, $21.00, (1994).
- *Macomb County Guide to Instructional Programs and Units.* Reviews of new teaching units and programs by Macomb County teachers. Available from Anchor Bay Schools, 810-725-2861.
- *Eisenhower National Clearinghouse for Mathematics and Science Education.* Ohio State University, 1929 Kenny Road, Columbus, OH 43210-1079, 614-292-7784
- *Science Curriculum Resource Handbook.* Kraus International Publications, 358 Saw Mill River Road, Milwood, NY, 10546-1035, 914-762-2200/800-223-8323 FAX: 914-762-1195, (1992).
- *Resources for Teaching Elementary School Science,* National Science Resources Center. National Academy Press, 2101 Constitution Avenue, NW, Washington, DC 20418, (1996), 800-624-6242.
- *The Guide to Math & Science Reform: An interactive resource for the education community,* available for Macintosh and MS-DOS/Windows computers. The Annenburg/CPB Math and Science Project, P.O. Box 2345, South Burlington, VT 05407-2345, 800-965-7373.

Assessment

MEAP Science Framework and High School Proficiency Test Blueprint are available from the MEAP Office, Michigan Department of Education, 517/373-8393.

Using MEAP and HSPT Results to Improve Teaching and Learning, Michigan Department of Education, 517/373-0454.

Science Assessment Guide and Model Assessment Items. The Michigan Assessment Team. Available from Dick Braun, 8170 Brookville Rd., Plymouth, MI 48170. 313/453-2379. (Provides samples of "authentic" classroom assessment items.)

Professional Development

"Standards for Professional Development," Michigan Department of Education/State Board of Education, available through the MDE School Development Office (517/373-1831), and in *Michigan Curriculum Framework*, listed earlier. (1996). (These standards provide broad guidelines for creating the contexts, content, and processes of effective professional learning situations.)

National Science Education Standards for Professional Development, listed earlier.

Developing and Supporting Teachers for Science Education in the Middle Years. Loucks-Horsley, Brooks, Carlson, Kuerbis, Marsh, Padilla, Pratt, and Smith. The National Center for Improving Science Education, 300 Brickstone Sq. Suite 950, Andover, MA 01810, 508-470-0098. (1990).

Computers & Technology

Only the Best: The Annual Guide to the Highest Rated Educational Software and Multimedia. Association for Supervision and Curriculum Development, 1250 North Pitt Street, Alexandria, VA 22314-1453, 703-549-9110. (1996)

The 1996 Educational Software Preview Guide. International Society for Technology in Education, Customer Service Office, 480 Charnelton Street, Eugene, Oregon 97401-2626, 800-336-5191 Fax: 541-302-3778. (1996)

Plugging In: Choosing and Using Educational Technology. Jones, Valdez, Nowakowski, Rasmussen. North Central Regional Educational Laboratory, 1900 Spring Road, Suite 300, Oak Brook, Illinois 60521, 708-571-4700.

Michigan Mathematics and Science Centers

Schools, communities, colleges and universities, businesses, industries, and state government have joined forces to create Centers around our state to improve mathematics and science education.

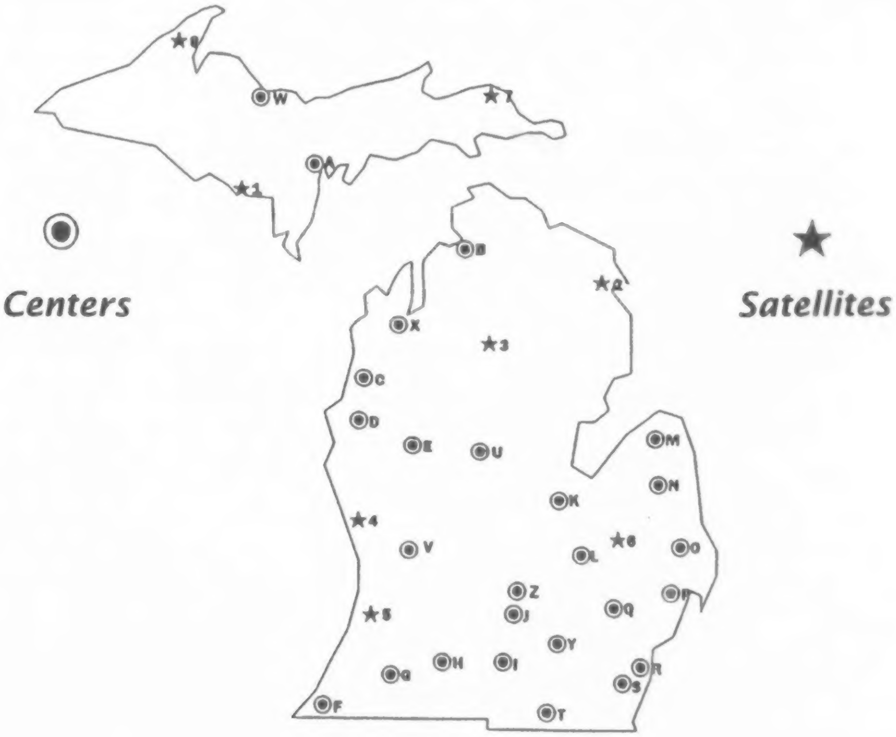
Michigan Mathematics and Science Centers help communities, schools, educators and students improve their schools. As knowledgeable partners, Centers ensure that various initiatives in mathematics and science are coordinated within a region, that resources are used efficiently, and that programs and services address the real needs of educators and the students with whom they work.

Centers are not the sole providers of services in mathematics and science. Rather, Centers are key elements in the infrastructure that connects a variety of stakeholders within a region and across the state in ways that foster collaboration, cooperation and continual improvement in teaching and learning.

Basic Services Provided by Centers

Every Center provides:
Leadership
Student Services
Professional Development
Curriculum Support
Community Involvement
Resource Clearinghouse

And interacts with:
Educators and Students
Parents and Communities
School Districts
Higher Education
Education Organizations
Business and Industry



1996-97 Mathematics and Science Centers, Satellites, and Statewide Project

Cd	Center Name	Director	Phone	E-Mail
1	Dickinson-Iron Area M/S Center	Dee Benjamin	906/779-2690	dobenjam@diisd.k12.mi.us
2	AMA/Iosco M/S Center	James O'Farrell	517/354-3101	ofarrelj@ns.amaesd.k12.mi.us
3	COOR S/M Satellite (COSMOS)	Jan Farmer	517/275-5137	Farmerj@K2.Kirtland.cc.mi.us
4	Muskegon Cnty Area M/S Ed Center	Gregg Zulauf	616/777-1808	GAZULAUF@aol.com
5	Allegan County Area M/S Ed Center	Amy Oliver	616/673-3121	aoliver@accn.org
6	Lapeer County M/S Center	Pete McCreedy	810/664-5917	pmccreed@edcen.ehhs.cmich.edu
7	EUP M/S Center	Nina Klein	906/635-2126	nklein@lakers.lssu.edu
8	Copper Country M/S Center	Jean Ellis	906/482-4250	jellis@edcen.ehhs.cmich.edu
A	Northwoods Math Science Center	Debra Homeier	906/786-9300	dhomeier@up.net
B	SEE-North	Mary Whitmore	616/348-9700	mwhit@sunny.ncmc.cc.mi.us
C	Manistee Regional M/S Access Center	Rick Farfsing	616/848-4858	rfarfsin@manistee-isd.k12.mi.us
D	Mason-Lake Oceana M/S Center	Marsha Barter	616/845-6211	barter@westshore.cc.mi.us
E	Mecosta-Osceola M/S/T Center	Paul Bigford	616/796-3543	pbigford@edcen.ehhs.cmich.edu
F	Berrien County M/S Center	Dennis Lundgren	616/471-7725	dlundgre@remc11.k12.mi.us
G	Kalamazoo Area M/S Center	Wayne Schade	616/337-0004	WSchade@KAMSC.k12.mi.us
H	Battle Creek Area M/S Center	Charles DeRemer	616/965-9440	Charles_DeRemer@fc1.glfn.org
I	Jackson County M/S Center	Patrick Traster	517/787-2800	traster@scnc.jcisd.k12.mi.us
J	Capital Area Sci/Math Center (CASM)	Pete Vunovich	517/487-2276	pvunovic@isd.ingham.k12.mi.us
K	SVSU Regional M/S Center	Walter Rathkamp	517/790-4114	rathkamp@tardis.svsu.edu
L	Genesee Area M/S/T Center	Johanna Brown	810/768-4495	jbrown@artoo.gisd.k12.mi.us
M	Huron M/S/T Center	Linda Fawcett	517/269-6406	lfawcett@edcen.ehhs.cmich.edu
N	Sanilac County Sci/Math Center	Noni Miller	810/648-4700	nmiller@genesee.freenet.org
O	St. Clair M/S/T Network	Terry Parks	810/364-8990	tparks@stclair-isd.k12.mi.us
P	Macomb County M/S/T Center	Gerard Putz	810/228-3467	gputz@edcen.ehhs.cmich.edu
Q	Oakland Schools S/M/T Center	David Housel	810/683-7476	dchousel@oakland.k12.mi.us
R	Detroit M/S Centers	Juanita Clay Chambers	313/494-1610	jclaycha@sun.science.wayne.edu
S	Wayne County M/S Center	Cheryl Vaughan	313/467-1375	vaughac@wcresa.k12.mi.us
T	Hillsdale-Lenawee-Monroe M/S Center	Tom Green	517/265-1668	tgreen@mail.lisd.k12.mi.us
U	Central Michigan SMTC	Claudia Douglass	517/774-4387	claudia.douglass@cmich.edu
V	Regional M/S Center(GVSU)	Mary Ann Sheline	616/895-2265	shelinem@gvsu.edu
W	The Seaborg Center-NMU	Peggy House	906/227-2002	phouse@nmu.edu
X	Grand Traverse Regional M/S/T Center	Gary Money	616/922-7876	gmoney@edcen.ehhs.cmich.edu
Y	Livingston/Washtenaw M/S Center	Carolyn Hannum	517/546-5550	channum@edcen.ehhs.cmich.edu
Y	Livingston/Washtenaw M/S Center	Sandy Trosien	331/994-8100	strosien@isd.wash.k12.mi.us
Z	Tune in Math and Science	Lori Hudson	517/353-0722	20204LJH@msu.edu

Alternative Instructional Programs and Units

Interesting and engaging programs and units are now available for elementary, middle, and high school, as alternatives to traditional textbooks. Included among those new programs is a small set of units written directly from the state science objectives (the New Directions Science Teaching Units). Other programs are based on similar reform ideas. While the state does not recommend any particular teaching materials, the list of alternative materials presented on the following pages is a good sample of new materials that a district might want to investigate. As you do, focus on the criteria listed below.

These alternative instructional materials have not been carefully evaluated in actual classrooms by Michigan teachers. If you or your colleagues use any of these materials and would like to share an evaluation of them with other Michigan teachers—both the positives and negatives—please send it to the address in the introduction. Base your evaluation on the criteria listed below. If you use teaching materials that are not presently in this section, and you highly recommend them because they meet many or all of the criteria below, please let us know about them, and we will consider listing them in updates to this section.

Criteria for evaluating instructional materials:

1. **Do the materials emphasize understanding over content coverage?**
   A. Is their main emphasis on the big ideas of science, especially as represented in the *Michigan Essential Goals and Objectives/Content Standards and Benchmarks?*
   B. Do they start with questions about these big ideas, rather than by presenting answers only?
   C. Do they give students multiple opportunities in different contexts to reflect on and practice the use of new ideas and skills?
   D. Do they emphasize how science knowledge is gained and justified, by allowing students to conduct significant inquiries and actively debate scientific ideas?
   E. Does the assessment emphasize understanding over memorization?

2. **Do the materials emphasize learning that is useful and relevant outside of school?**
   A. Do they allow students to build on their experiences?
   B. Do they give students ample opportunities to experience—not just read about or watch on videos—the phenomena and systems of the real world?
   C. Do they emphasize application of knowledge rather than recall of factual information?

3. **Do the materials emphasize scientific literacy for all students?**
   A. Do they provide support for diverse learners?
   B. Do they provide strategies for building a classroom community of learners?
   C. Do they help teachers understand and respond to individual learners?

4. **Do the materials promote interdisciplinary learning?**
   A. Do they show how several content areas within science and technology are often necessary for solving real-world problems?
   B. Do they offer bridges to language arts, mathematics, and art in ways that facilitate the development of science concepts?
   C. Are there bridges to social studies?

5. **Do the materials provide support systems for teachers?**
   A. Does the instruction presented by the unit provide a model for teachers to improve science teaching?
   B. Are the materials provided specifically for the teacher easily usable by the teacher?
   C. Are workshops available to help teachers understand how to use the materials?

Modules (2 to 8 week units)

New Directions Teaching Units

(K-10th grades)

Developed by:
Michigan Science Education Resources Project
Theron Blakeslee, Project Director
Michigan Department of Education
P.O. Box 30008
Lansing, MI 48909
517-373-0454

Available from:
Battle Creek Mathematics and Science Center
765 Upton Avenue
Battle Creek, MI 49015-4894
616-965-9593

New Directions are interdisciplinary units emphasizing particular concepts in life, earth or physician science, based directly on the Michigan Essential Goals and Objectives in Science Education. Each unit includes a teacher's guide; overhead transparency masters; and corresponding student activity charts for 6 to 8 weeks of activity-oriented sequenced lessons.

	Life Science	Physical Science	Earth Science
Kindergarten, 1st or 2nd grades		Constructing Toys and Concepts	
2nd and 3rd grades			Weather in our Neighborhood (Under development)
3rd and 4th grades	Running on Plants		Cloudy days (Under development)
5th, 6th and 7th grades	The Lives of Plants	Hard As Ice & Steamed Up! (two units)	
8th, 9th and 10th grades	Food, Energy and Growth	Chemistry That Applies	

Science and Technology for Children

(1st-6th grades)

Developed by:
National Science Resources Center
Smithsonian Institute—National
Academy of Sciences
Arts & Industries Bldg., Rm. 1201
Washington, DC 20560
202-357-2555

Available from:
Carolina Biological Supply Company
2700 York Road
Burlington, NC 27215
800-334-5551

STC consists of twenty-four teaching units which can be used either as a complete elementary science program or as a supplement to an existing program. Each unit includes a teacher's guide and student booklet for four to eight weeks of activity-oriented sequenced lessons. Kits of materials for the units may also be ordered from the supplier.

	Life Science	Earth Science	Physical Science	Technology
1st grade	Organisms	Weather	Solids and Liquids	Comparing and Measuring
2nd grade	The Life Cycle of Butterflies	Soils	Changes	Balancing and Weighing
3rd grade	Plant Growth and Development	Rocks and Minerals	Chemical Tests	Sounds
4th grade	Animal Studies	Maps and Models	Food Chemistry	Electric Circuits
5th grade	Microworlds	Ecosystems	Structures	Floating and Sinking
6th grade	Experiments with Plants	Measuring Time	Machines and Inventions	Magnets and Motors

Insights: An Elementary Hands-On Inquiry Science Curriculum

(K-6th grades; can be used as separate modules or as a complete curriculum)

Developed by:
Education Development Center, Inc.
c/o Diane Redonnet
55 Chapel St.
Newton, MA 02158
800-225-4276

Available from:
Optical Data Corporation
30 Technology Drive
Warren, NJ 07059
800-524-2481

Insights is an elementary science program consisting of 17 thematic modules which can be used together as a complete program or as individual modules in conjunction with existing programs. Each module focuses on a limited number of concepts and themes in depth and breadth, integrating the science disciplines and technology, while developing attitudes, skill, knowledge and values. They are designed to be responsive to the needs of the urban school.

	Modules
Kindergarten-1st grades	Balls and Ramps Myself and Others The Senses Living Things
2nd-3rd grades	Lifting Heavy Things Liquids Sounds Habitats Growing Things
4th-5th grades	Circuits and Pathways Changes of State The Mysterious Powder Reading the Environment Bones and Skeletons
6th grade	Structures There Is No Away Human Body Systems

Kid's Network: Nationwide Computer-based Interactive Inquiry

(4th-9th grades)

Developed by:
National Geographic Society, with
Technical Education Research Center
2067 Massachusetts Avenue
Cambridge, MA 02140
617-547-0430

Available from:
National Geographic Society
Educational Services
PO Box 98018
Washington, DC 20090
800-368-2728

National Geographic Kids Network science units make direct connections with social studies and geography, emphasizing environmental issues, global telecommunications and the student as a collaborating research scientist. The units include software, software manual, teacher's guide, student handbooks, wall maps, scientific materials, activity sheets and site license to copy software. Tuition includes network access, time on network, a unit scientist and hot-line support. Each unit is offered at least three times per year and is eight weeks long. Equipment required includes a Macintosh, IBM, or Apple II GS computer (preferably with color monitor), printer, modem and phone line.

Units for 4th-6th Grades						
Hello!	What's in Our Water?	Solar Energy	What Are We Eating?	Acid Rain	Too Much Trash?	Weather in Action

Units for 6th-9th Grades			
Soil: What is it good for?	Sound: How loud is too loud?	Oxygen: How do our bodies get the oxygen we need?	Surface water: How polluted is our local surface water?

A World in Motion: Collaborative Technology Education With Society of Automotive Engineers
(4th–6th grades)

Developed by and available from:
Education Program Coordinator, SAE, Inc.
400 Commonwealth Dr.
Warrendale, PA 15096-0001
412-776-4841

A World in Motion includes three eight-week print and video programs that emphasize hands-on discovery of science principles in a cooperative learning setting. Components include learning cards, wall charts, video and teacher's guide. Unique feature is the involvement of volunteer SAE engineers in the classroom.

	Teacher-Directed	Independent Learning
4th grade	Skimmer Regatta 1. Force and Motion 2. Friction and Motion 3. Air Resistance and Motion 4. Air and Motion 5. Mass and Balance	1. Get Moving 2. Power Up 3. Slow Down 4. Move Ease 5. Airborne
5th grade	Option Derby 1. Wheels and Axles 2. Friction 3. Streamlining 4. Loads and Balance 5. Balloon Power	1. Get Moving 2. Power Up 3. Slow Down 4. Move Ease 5. Airborne
6th grade	Can Crusher Competition 1. Levers 2. Wheel and Axle, Inclined Plane 3. The Screw 4. Pulley 5. Design, Build and Communicate	1. Get Moving 2. Power Up 3. Slow Down 4. Move Ease 5. Airborne

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Science Sleuths: Fun Science Mysteries for Middle School Sleuths (6th–9th grades)

Developed by:
Larry Rainey and Star Bloom
University of Alabama
PO Box 870167
Tuscaloosa, AL 35487

Available from:
Hold, Rinehart & Winston, Inc.
Order Fulfillment Dept.
6277 Sea Harbor Dr.
Orlando, FL 32887-4410
800-225-5425

Science Sleuths is an interactive science program that focuses on problem solving. Students work in teams to solve 24 inquiry-based science "mysteries." Each mystery begins with a humorous dramatization that encourages students to investigate the situation. All clues and resources are found on the laserdisc. Students can study test samples, experiments, expert testimony, articles, photos, charts, and other data. After careful research and analysis, students develop a logical explanation and present their findings in a lab report. While scientific skills are needed to solve the mysteries, the focus is on encouraging students to articulate and test theories by collecting and evaluating data from various sources. Components include laserdisc, barcoded teacher's manual, sleuth resource directories and sleuth resource guidebook (also available in Spanish). Hardware required includes a standard laserdisc player, barcode reader and/or remote control and standard television monitor.

Mysteries

The Traffic Accident
The Plainview Park Vandals
The Biogene Picnic
The Blob
Exploding Lawn Mowers
The Energy Mystery House
Burning Barns & Exploding Silos
The Missing Beach
Dead Fish on Union Lake
Neo-Cassava: The Tropical Miracle
Green Thumb Plant Rentals #1
A Day at the Races
Fogged Photos
Noises in School
Fortune or Fraud?
Twins or Not?
The Lost Mining Probe
The Collapsing Bleachers
The Misplaced Fossil
Green Thumb Plant Rentals #2
The Nature House Malady
The Moving Monument
The Mystery Fog
The Crashing Computers

GEMS: Great Explorations in Math and Science

(K-9th grades)

Developed by and available from
Lawrence Hall of Science
University of California
Berkeley, CA 94720
510-642-7771

GEMS materials consist of teacher's guides, data sheets and student units, and range in appeal from preschool through high school. These 30 publications integrate math with life, earth, and physical science, fostering a "guided discovery" approach to learning. Materials are easily accessible, and lessons are written for teachers with little training in math or science.

Preschool-1st grades	Animal Defenses	
Preschool-3rd grades	Buzzing a Hive Hide a Butterfly	
Kindergarten-3rd grades	Liquid Explorations	
1st-3rd grades	Involving Dissolving	
4th-8th grades	Crime Lab Chemistry Hot Water & Warm Homes from Sunlight Cabbages and Chemistry Oobleck: What Do Scientists Do?	Fingerprinting Vitamin C Testing Quadice
5th-8th grades	Color analyzers Paper Towel Testing	
5th-9th grades	Bubble-ology Mapping Animal Movements Earth, Moon and Stars	
6th-9th grades	Animals in Action Convection: A Current Event	More Than Magnifiers River Cutters
6th -10th grades	Chemical Reactions Global Warming & The Greenhouse Effect Acid Rain Experimenting with Model Rockets	Discovering Density Earthworms Mapping Fish Habitats Height-O-Meters

Facets (Foundations and Challenges to Encourage Technology-based Science)

(6th-8th grades)

Developed by:
American Chemical Society

Available from:
Kendall-Hunt Publishing Co.
4050 Westmark Dr.
Dubuque, IA 52002
800-258-5622

The twenty-four FACETS modules were developed over a three-year period by the American Chemical Society, funded in part by the National Science Foundation. The program's history also includes extensive field testing involving 10,000 students at fifteen sites throughout the nation.

Series A	**Series B**	**Series C**
Changing Shorelines	A Sunken Ship	Investigating Populations
Shrinking Farmlands	Acid Rain	Managing Crop Pests
Earthquakes	Cleaning Water	Climate and Farming
Investigating a Building	What's in Our Food	Oil Spills
Investigating Packaging	Food From Our Land	Energy for the Future
Food Substitutes	Structures and Behavior	Threads
Keeping Fit	Communicable Diseases	Transportation Systems
Weather and Health	Growing Older	Handling Information

The Earth Generation/The Great Lakes
(6th–8th grades)

Developed by:
The Dow Chemical Company,
The U.S. Environmental Protection Agency,
The Michigan Audubon Society and
The Earth Generation

Available from:
The Earth Generation
Box #2005
Midland, MI 48641-2005
800-221-1663
FAX: 517-631-7530

The Earth Generation/The Great Lakes Kit consists of a teacher/student videotape, an Educator's Guide, lab and field-based activities, vocabulary list, career descriptions, pre- and post-project assessments and student and teacher evaluation forms. This material is indexed to correspond with Michigan math and science objectives. Limited quantities are available. The Earth Generation has other supplemental materials available.

	Great Lakes Topics
6th–8th grades	Run-off pollution Point-source pollution Solid waste Airborne pollution Wetlands destruction Contaminated aquatic life

Breakthroughs: Strategies for Thinking
(K–7th grades)

Developed by:
North Central Regional Education Laboratory
1900 Spring Road Suite 300
Oak Brook, IL 60521
708-571-4700

Available from:
Zaner-Bloser, Inc.
P.O. Box 16764
Columbus, OH 43216-6764
614-487-2896

Breakthroughs are short units based on real-world problems in science and social studies, that help students learn strategies and skills for thinking. The units are based on the learning theory found in *Dimensions of Thinking: A Framework for Curriculum and Instruction* (Marzano, R., et al., ASCD, 1988) and *Strategic Teaching and Learning: Cognitive Instruction in the Content Areas* (Jones, B.F., et al., ASCD, 1987).

	Unit Title
Kindergarten–7th grades Sampling of Over 50 Units Available	Plants and People as Partners? Are You Really Hungry Martians—Fact or Fiction Dolphins—Our Newest Allies? Where Have All the Condors Gone? Fuel Today...Gone Tomorrow? Where Does Garbage Go? Rain Forests—The Lungs of the Earth? The Muddy River, the Sticky Sea, and Me? Communities: A Real Balancing Act?

FOSS, Full Option Science System

(K-6th grades)

Developed by:
Lawrence Hall of Science
University of California
Berkeley, CA 94720
510-642-7771

Available from:
Encyclopedia Britannica Educational Corp.
310 S. Michigan Avenue—6th floor
Chicago, IL 60604
800-554-9862

FOSS is a complete, modular science program that integrates hands-on, real world science with interactive multimedia materials. The FOSS program consists of 27 modules, covering life, earth and physical science, plus in grades 3-6, there are also modules in scientific reasoning and technology. Britannica also offers multimedia materials to accompany the printed FOSS materials. These include teacher overview and preparation videos, student videos and videodiscs with barcodes. Most materials are available in English or Spanish.

	Life Science	Physical Science	Earth Science	Scientific Reasoning and Technology
Kindergarten	Animals Two by Two Trees	Fabric Paper Wood		
1st-2nd grades	Insects New Plants	Balance and Motion Solids and Liquids	Air and Weather Pebbles, Sand, and Silt	
3rd-4th grades	Human body Structures of Life	Magnetism and Electricity Physics of Sound	Earth Materials Water	Ideas and Inventions Measurement
5th-6th grades	Environments Food and Nutrition	Levers and Pulleys Mixtures and Solutions	Landforms Solar Energy	Models and Designs

CEPUP, Chemistry Education for Public Understanding Program

(6th-9th grades)

Developed by:
Lawrence Hall of Science
University of California
Berkeley, CA 94720
510-642-7771

Available from:
Addison Wesley Publishing Company
1 Jacob Way
Reading, MA 01867
800-447-2226

CEPUP offers a series of activity-based instruction modules that integrate chemical and earth science concepts and processes with societal issues. Each two-week module uses an inquiry-based problem-solving approach to learning that emphasizes evidence-based decision making. The project links schools, education organizations, community groups, scientists, and industry, and provides materials, leadership training, community outreach, and a National Fellows program. Lawrence Hall of Science is also developing yearlong courses (SEPUP), based on CEPUP.

Module Titles Available
Chemical Survey/Solutions and Pollution
Investigating Groundwater: The Fruitvale Story
Investigating Hazardous Materials
Investigating Chemical Processes: Your Island Factory
Plastic in our Lives
Chemicals in our Foods: Additives
Determining Threshold Limits
Toxic Waste: Treatment and Disposal
Waste Hierarchy: Where is "Away"?
Investigating Household Chemicals
Risk Comparison

Survival Strategies

(7th-10th grades)

Developed by and available from:
Bronx Zoo Education Department
Bronx Zoo/Wildlife Conservation Park
Bronx, New York 10460
800-937-5131

Survival Strategies is a multi-media life science curriculum which enables students to explore issues related to wildlife survival in the 21st century. The units cover many curricular objectives including ecology of organisms, environmental science, natural resource use, ecosystem functions, and population biology. The kit consists of 23 lesson units ranging in length from 1-4 classroom periods each, teachers manual, resource books, worksheets, discovery cards, audio cassettes, games and photo cards.

	Units
Grades	Life Cycles and Populations
7th-10th	Competition and Predation
	Wildlife and People

Hydroponics: A video and hands-on program for high schools

Developed by and available from:
Harley N. Smith, Exec. Producer
1600 Boynton Dr.
Lansing, MI 48917

The program materials include videos and teachers guides to supplement and extend high school biology. Kits are available for setting up hydroponics labs in schools.

Supplemental activities:
Can be used within a locally-developed unit, block, or curriculum:

The Voyage of the Mimi
(4th-8th grades)

Developed by:
Bank Street College of Education
Cambridge, MA

Available from:
Sunburst
101 Castleton St.
P.O. Box 100
Pleasantville, NY 10570-0100

The Voyage of the Mimi combines video, print and software to create an interdisciplinary, thematic, multimedia approach to middle school education. The first voyage consists of 13 fifteen-minute video episodes and is the story of a scientific expedition to study whales. The second voyage consists of 12 fifteen-minute episodes and is the story of archaeologists in search of a lost Mayan city and looters who may have already found it. These episodes are interspersed with expeditions to places where real scientific research is being done.

	Videotapes and Videodiscs	Software	Print
The Voyage of the Mimi	The Voyage of the Mimi	A Field Trip into the Sea Maps and Navigation Whales and Dolphins Ecosystems Introduction to Computing	Theme Guide The Voyage Continues… Language Arts Guide Student Book Overview Guide
The Second Voyage of the Mimi	The Second Voyage of the Mimi What is the Second Voyage of the Mimi? Explore and Discover	Maya Math A Field Trip to the Sky A Field Trip to the Rainforest Scuba Science Sun Lab	Overview Guide Theme Guide Student Book Social Studies Resources Guide

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WOBS, Windows on Beginning Science
(Pre kindergarten-2nd grades)

Developed by and available from:
Creative Publications
788 Palomar Avenue
Sunnyvale, CA 94086
800-624-0822

Windows on Beginning Science emphasizes the development of scientific thinking rather than the acquisition of specific scientific principles. By participating in a series of motivating and problem-solving investigations, children are guided to explore, observe, discover relationships, record and communicate their observations about the world around them. Six resource books each contain more than 25 lessons, plus a mangement guide that includes a skills inventory, materials list, safety tips, reproducible masters and data sheets. A complete materials kit is also available.

Resource Book Titles
Seeds and Weeds Insects and Other Crawlers Rocks, Sand, and Soil Water and Ice Constructions Light, Color and Shadows

Classroom GEMS: Groundwater Education in Michigan Schools

(K-6th grades)

Developed by and available from:
SEE-North (Science and Environmental Education)
03001 Church Rd.
Petoskey, MI 49770
616-348-9700
FAX: 616-348-1085

Classroom GEMS is designed to provide Michigan's citizens of tomorrow with the knowledge and skills to understand, value, protect, and renew our precious groundwater resources. Twenty-three activities include hands-on investigations, music, games, books and visual aids that span many subject areas, including science, social studies, art, language arts and math. Inservice workshops are available.

	Activity Titles
Kindergarten-6th grades	I am Water Water Words
Kindergarten-3rd grades	Get Wet! Water Wheels Storm Symphony Cloudmakers Earth Search Get Down!
1st-3rd grades	Water Wigglers
2nd-3rd grades	Mystery Solutions
2nd-6th grades	It's Not Just the Pond! Plants and Pollutants Shout It Out! Water Watchers
4th-6th grades	It's a Wet, Wet World Groundwater on the Go Stick With It! Who's To Blame? Dirty Water Underground Keep It Clean! How Clean is Clean? Keep It Afloat! What's In My Backyard?

WISE Project: Waste Information Series Education

(K-12th grades)

Developed by:
Michigan United Conservation Clubs
and the Michigan Department of Natural Resources
2101 Wood St.
Lansing, MI 48912

Available from:
Michigan United Conservation Clubs
2101 Wood St.
Lansing, MI 48912
517-371-1041

WISE was originally developed by the Michigan Department of Natural Resources and more recently updated by the Michigan United Conservation Clubs. WISE consists of interdisciplinary activities dealing with solid waste issues and pollution prevention. The materials include grade-level specific student readers. Access to the materials requires a four hour inservice, and the materials are provided free of charge to Michigan teachers and their students. Typically, the local community solid waste coordinator is involved in the inservice.

	Student Reader Titles
Kindergarten-3rd grades	Trash Can Gazette
4th-6th grades	WISE Today
7th-9th grades	Slime Magazine
10th-12th grades	Get WISE

AIMS, Activities Integrating Mathematics and Science

(K-9th grades)

Developed by and available from:
AIMS Education Foundation
P.O. Box 8120
Fresno, CA 93747-8120
209-255-4094

AIMS materials provide grade-appropriate activities in a flexible format integrating mathematics, science, and social science. The 25 student modules incorporate real-world hands-on activities; design, construction and use of appropriate data records; utilization of graphic/pictorial data displays; and hypothesizing, inferring and generalizing.

	Student modules
Kindergarten-1st grades	Fall into Math & Science Glide into Winter with Math & Science Spring into Math & Science
Kindergarten-3rd grades	Primarily Physics Primarily Plants
Kindergarten-6th grades	Primarily Bears Critters
2nd-6th grades	Water Precious Water
2nd-8th grades	Mostly Magnets
3rd-4th grades	Jaw Breakers and Heart Thumpers Hardhatting in a Geo-World Popping With Power Overhead and Underfoot
4th-9th grades	Soap Films and Bubbles Finding Your Bearing Electrical Connections
5th-9th grades	Math—Science (A Solution) The Sky's the Limit From Head to Toe Fun with Food Floaters and Sinkers Down to Earth Our Wonderful World Pieces and Patterns Out of this World

PLT: Project Learning Tree (K-8th grades)

Developed by:
American Forest Foundation and the
Western Regional Environmental Education Council
Director, Kathy McGlauflin
1111 19th Street NW
Washington, DC 20036

Available from:
Karen VanDyke
MEAD Paper/Woodlands Division
PO Box 1008
Escanaba, MI 49829
906-786-1660 Ext. 2187

Project Learning Tree is an environmental education product of educators, scientists, resource managers, and industry professionals, field tested and revised after 20 years in the classroom. The goal of PLT is helping students learn how to think, not what to think. The 96 activities are indexed in several useful ways, including by grade level, subject, time considerations, and skills.

96 Activities Titles are grouped by these Themes:
Diversity Interrelationships Systems Structure and Scale Patterns of Change

Year-long programs

Life Lab Science: A Multimedia Science Program

(K-6th grades)

Developed by:
Life Lab Science Program
1156 High Street
Santa Cruz, CA 95064
408-459-2001

Available from:
Videodiscovery, Inc.
1700 Westlake Ave. N., Suite 600
Seattle, WA 98109-3012
800-548-3472

Life Lab Science integrates earth, life and physical sciences in a garden context: Its constructivist format encourages students to incorporate experiences from outside the classroom. Students perform hands-on activities and experiments in their "living laboratory," which can be as small as a tray of seedlings or as large as a full-scale garden. Each grade works with a wide variety of multimedia materials, including a videodisc, audio tape, poster, calendar, and optional gardening kits. Other components include a teacher's resource book, student lab books (also available in Spanish) and garden guide. Hardware required includes standard videodisc player, barcode reader or remote control, standard television monitor. Optional computer software is also available.

	Unit Titles
Kindergarten: Explorations	Exploring Our Senses Exploring Soil Exploring Water Exploring Plants Exploring Garden Animals Garden Celebration
First Grade: Diversity and Cycles	Sensing Our World Investigating Seeds Exploring Soil Observing Earth's Cycles Investigating Weather Exploring Plant Life Exploring Animal Life Investigating Garden Homes
Second Grade: Change	Sensing Changes Investigating Plants Investigating Water Investigating Air Investigating Food Chains Investigating Resources Conserving Resources
Third Grade: Structure-Function	Sensory Exploration Seeds Soil Weather and Climate Tools Plants Garden Animals Habitats
Fourth Grade: Interactions	Habitats Nutrients Water Sunlight Food Web Garden Ecosystems Sustainable Systems
Fifth Grade: Change Over Time	Adaptations Energy Seasons Climate Soil Plants and Animals Growing Together

The Growing Classroom: Garden-Based Science

(2nd–6th grades)

Developed by:
Life Lab Science Program
1156 High Street
Santa Cruz, CA 95064
408-459-2001

Available from:
Addison-Wesley Publishing Co.
Supplemental Publishing Division
1 Jacob Way
Reading, MA 01867-9975
800-447-2226

The Growing Classroom uses a combination of exteriential activities taught within the context of the "Living Laboratory," an outdoor garden or planter box, an indoor growing center, or both. This laboratory provides students with the opportunity to plan, create, and care for their own environment. In the process, they ask questions about their environment, and make observations, research topics, and set up experiments in search of answers. The Life Lab Science Program has two basic goals: to assist schools in developing living laboratories in which young students can discover their world through scientific exploration; and to provide curriculum and inservice so that every teacher feels comfortable teaching science in a living laboratory. The Growing Classroom provides year-round activities organized in units related to specific concepts and topics.

Science Units	Nutrition Units
Let's Work Together We Are All Scientists The Living Earth Growing Living Laboratory Cycles and Changes Interdependence Garden Ecology Garden Creatures Climate	Food Choices Nutrition Consumerism

DASH: Developmental Approaches in Science and Health

(K–6th grades)

Developed by:
University of Hawaii
Curriculum Research & Development Group
College of Education
1776 University Ave.
Honolulu, HI 96822
808-956-6918

Available from:
Frank Mattas, Director
Educational Merchandising & Consulting
1436 Spring Valley Dr.
Roseville, CA 95661
916-782-3773
FAX: 916-782-9071

DASH is an elementary science, health and technology program, designed to narrow the gap between the way science is taught and the way science is used in a technological health-oriented society. DASH fuses science and health through medicine, nutrition, and other biological technologies. DASH connects science, health and technology to mathematics, language, music, social studies, and art in ways that bring students to an understanding of the integration of the human experience. The developmental approach means that DASH begins with students' basic biological needs to grasp basic concepts and to form a foundation on which to build ideas of increasing complexity, developing concepts and skills that are concrete and verifiable in children's immediate experiences.

Activity Clusters in Kindergarten–6th grades
Learning Time, Weather and Sky Animals Plants Food and Nutrition Health and Safety Wayfinding and Transportation Energy and Communication Conservation, Recycling and Decomposition Matter, Space and Construction

FAST: Foundational Approaches in Science Teaching

(3 years in 6th–12th grades)

Developed by:
University of Hawaii
Curriculum Research Development Group
Donald Young, Project Manager
1776 University Ave.
Honolulu, HI 96822
808-956-7863
FAX: 808-956-4414

Available from:
Frank Mattas, Director
Educational Merchandising & Consulting
1436 Spring Valley Dr.
Roseville, CA 95661
916-782-3773
FAX: 916-782-9071

FAST is an interdisciplinary, environmental science program which emphasizes foundational concepts and methods of physical, biological, and earth sciences and relates them to practical issues of human use of environments. There are three levels of FAST designed for use as year-long programs in middle, junior, and senior high schools. Within each level, students experience each of three strands concurrently: Physical Science, Ecology and Relational Study. Classroom sets of FAST materials are available only to teachers who complete a FAST teacher institute.

	Physical Science	Ecology Strand	Relational Study
Level 1: The Local Environment	1. Introduction to the Properties of Matter 2. Changes of State in Matter 3. Temperature and Heat	1. Plant Growth 2. The Physical Environment 3. Animal Care 4. Field Ecology	1. Air Pollution
Level 2: The Flow of Matter and Energy through the Biosphere	1. Light and Heat 2. Evidence for the Atomic Theory 3. Model of Matter	1. Primary Production 2. Ecological Systems 3. Productivity in Ecosystems	1. World Food Production
Level 3: Change over Time	1. Measurement of force, work, gravity and energy 2. Mountain formation, weathering, erosion 3. Theories of the origin and structure of the universe 4. Structure of molecules 5. Stellar evolution	1. Theories for molecular evolution and the origin of life on earth 2. Probabilities of how life forms have changed over time 3. Local ecosystems and the interactions of populations	Students consider the problems of resource depletion, overpopulation, energy consumption

Science for Life and Living: Integrating Science, Technology, and Health

(K–6th grades)

Developed by:
BSCS
Colorado Springs, CO

Available from:
Kendall-Hunt Publishing Co.
4050 Westmark Dr.
Dubuque, IA 52002
800-258-5622

Science for Life and Living: Integrating Science, Technology, and Health, is a complete Kindergarten through grade 6 activity-based curriculum that incorporates education in science, technology, and health in an active and cooperative learning environment. Major concepts and skills integrate the three disciplines.

Teacher's Editions outline the elements of cooperative learning: team sizes, team tasks and goals, materials needed, and skills that students should apply.

Eco-Inquiry

(5th-6th grades)

Developed by:
Institute of Ecosystem Studies
New York Botanical Garden
Box AB Route 44A
Millbrook, NY 12545-0129
914-677-5343

Available from:
Kendall-Hunt Publishing Co.
4050 Westmark Dr.
Dubuque, IA 52002
800-258-5622

Eco-Inquiry is a school science program that transforms classrooms into centers of ecological research. During the 10-12 week program composed of five sequential units, students build understanding of key processes in nature, become aware of how scientists create knowledge, and develop their own capacities to do likewise. The Eco-Inquiry program materials include a curriculum guide; activity sheet masters an ecology background book for teachers; ecology reference materials for the classroom; a kit of lesson props and experiment equipment; and a journal, folder and "Rita" novelette for each student.

	Session Titles	
Unit 1: Fundamentals	Ecosystem Encounter Mini-World The "Stuff" of Life Burial Box It's All in the Flow Taking Stock of Knowledge Acting on Science A World Premiere	
Unit 2: Science and Scientists	Dress the Scientist Exploring the Scientific Self Company Codes The Ladder of Growth	
Unit 3: Learning to Inquire	Research, One Step at a Time Ready, Set, Experiment! Decomposer Data Making Sense of it All	
Unit 4: Ecology Research: Challenge and Cooperation	A Challenge from GROW Planning for Action Peer Review A Final Design GROW Gets an Answer	Up and Running Keeping Trace Decisions, Decisions
Unit 5: The Inquiring Mind: From Science to Everyday Life	Rita	

Middle School Science & Technology

(6th-8th grades)

Developed by:
BSCS
Colorado Springs, CO

Available from:
Kendall-Hunt Publishing Co.
4050 Westmark Dr.
Dubuque, IA 52002
800-258-5622

This multilevel, integrated program utilizes hands-on activities in a cooperative learning environment to encourage the investigation of scientific concepts. The four major goals of Middle School Science & Technology are: to enhance students' learning of basic concepts and skills related to science and technology; increase the participation and success of underrepresented populations in science classes; improve students' understanding of how science and technology relate to their lives; and encourage the development of critical thinking and problem-solving abilities in studies.

Level A:	Investigating Patterns of Change
Level B:	Investigating Diversity and Limits
Level C:	Investigating Systems and Change

Active Physics

(5th-6th grades)

Developed by:
Center for the Enhancement of Science
and Mathematics Education
Northeastern University
716 columbus Avenue, Suite 378
Boston, MA 02120

Available from:
The Learning Team
10 Long Pond Road
Armonk, NY 10504-0217
914-273-2226

Active Physics is an NSF-supported curriculum project developed by the American Association of Physics Teachers (AAPT) and the American Institute of Physics (AIP) with assistance from the American Physical Society (APS). Active Physics is an alternative physics course for high school students who do not currently enroll in physics. Because of its limited prerequisite math and reading skills, this activity-based course can be successfully used with students from the 9th-12th grades. Active Physics uses thematic units and hands-on exploration of topics of intrinsic interest in six different units: sports, health and medicine, communications and information, home, transportation, and predicting the future.

BSCS Biology: A Human Approach

Developed by:
Biological Sciences Curriculum Study
5415 Mark Dabling Boulevard
Colorado Springs, CO 80918-3842

Available from:
Kendall-Hunt Publishing Co.
4050 Westmark Dr.
Dubuque, IA 52002
800-258-5622

This innovative program, appropriate for all students, incorporates many of the current recommendations from the reform literature into a course appropriate for the 10th grade biology classroom. The Human Version introduces a constructivist theory of learning, authentic assessment strategies, and cooperative learning into the high school biology classroom. This activity-based curriculum uses educational technologies, videodiscs, microcomputer-based laboratories and computer simulations to enhance learning and understanding. The program's thematic approach to biology encourages depth of coverage, rather than breadth, and with its emphasis on humans, this program presents biology in a context that will be relevant to students' lifelong learning.

Global System Science

Developed by and available from:
Lawrence Hall of Science
University of California
Berkeley, CA 94720-5200
510-642-0552
FAX 510-642-1055

Global Systems Science (GSS) is an integrated science program for the first year of high school concerned with global environmental change. The nine GSS student guides emphasize how men and women from a wide variety of fields work together to understand the interactions between natural systems and human activities. Global Systems Science program reflects the National Science Education Standards and has been evaluated to measure the impact of the GSS units on student learning.

Insights in Biology: An Introductory High School Biology Curriculum

Developed by and available from:
Education Development Center, Inc.
55 Chapel Street
Newton, MA 02158
617-969-7101 ext 2573
FAX 617-630-8439

This inquiry-based curriculum consists of five modules to be used in an introductory biology course either as a core for a complete biology course or as individual supplements for a curriculum already in place. It focuses on providing all students with the ability to understand fundamental principles in biology and with the skills to apply these understandings in their everyday lives. Insights strives to create a series of connected learning experiences framed within a story line that is relevant to students. The Teacher Guide and the Student Manual link together to form three explicit frameworks: a teaching/learning framework, a science thinking and process skills framework, and an assessment framework.

Prime Science

Developed by:
College of Chemistry
University of California
Berkley, CA 94720

Available from:
Kendall-Hunt Publishing Co.
4050 Westmark Dr.
Dubuque, IA 52002
800-542-6657

The Prime Science Program is a new National Science Foundation-funded, comprehensive, context-led, activity-based program aimed at secondary schools, grades 6-10. It builds on the Salters' Science Project materials, a well-tested, British, multi-disciplinary science program. There are five Teacher's Guides and five Student Books, one for each grade level. Concepts and skills are carefully developed and revisited from one year or one chapter to the next. In each year, the science includes life, earth/space and physical science, developing conceptual understanding and integrating mathematics, technology and decision-making. The science is rigorous, interesting and useful to the student. Among the major integrative themes that provide structure for grades six through ten are the processes of life, natural cycles and how we affect them, materials and how we use them, earth in space, properties of matter, and energy resources and transfer. Each new topic is introduced through an application or context which is of interest to a student of that age and which students know is important to their lives or to society. The science is then brought in as needed to understand the topic.

Principal PRIME SCIENCE Content Organization Topics	
PRIME SCIENCE is organized around 13 topics or themes which students and teachers can use to give structure to their ideas concerning the natural world.	
Topic 1:	Processes of Life
Topic 2:	Similarities and Differences in Living Things
Topic 3:	The Environment and How We Affect It
Topic 4:	Natural Cycles and How We Affect Them
Topic 5:	The Earth and Its Surroundings
Topic 6:	Materials and How We Use Them
Topic 7:	Explaining How Materials Behave
Topic 8:	How Materials Can Be Changed
Topic 9:	Sound Waves and Electromagnetic Radiation
Topic 10:	Using Electricity and Magnetism
Topic 11:	Energy Resources and Transfer
Topic 12:	Forces and How We Use Them
Topic 13:	The Earth and The Universe

Professional Development Needs Assessment

The following needs assessment can be used in conjunction with professional development planning, as outlined in Section 6 of the Science Education Guidebook.

This instrument is meant to be used at three levels:

Level one: As an **individual teacher** who is responsible for student learning in science, please read all of the categories describing skills related to CONTENT, INSTRUCTION and ASSESSMENT. Each subcategory is listed across a row and proficiencies are described. Place an "X" on each category that you feel describes part of your skill repertoire and is used in your classroom. Remember, we are all in the process of redefining what good science teaching is so don't be worried if you don't yet have an "X" in all categories or all rows. After completing the self-assessment, you will know better a set of standards and skills for good science teaching. Use the information when planning your own staff development opportunities.

Level two: As a **building unit,** schools are using the school improvement planning method and site-based decision making to use resources wisely to produce student success. A School Improvement Team, focused on planning staff development, should compile the individual results into a school profile so that money for staff development in science can be aimed at specific skills that are needed. Avoiding blanket, one-size-fits-all inservice will assure resource use connected to School Improvement goals. The resulting profile will allow groups or individuals to be directed to appropriate staff development.

Level three: Aggregated data from schools can be used at a **district level** to determine staff development activities that may be needed across several sites and may be more economically done as a combined effort. For more information on the variety of professional development activities available to you, see Section 6 of the Guidebook.

Developed by:
Judy Schaftenaar: Mt. Pleasant Public Schools, 201 S. University, Mt. Pleasant, MI 48858
Dave DeGraaf: Gratiot-Isabella Regional Educational Service District, P.O. Box 310, Ithaca, MI 48847
Theron Blakeslee: Michigan Department of Education, 608 West Allegan, Box 30008, Lansing, MI 48909

CONTENT

Major goals of Science Education (as listed in MEGOSE)

I know the four major goals of science education in Michigan.	I can describe these goals to a colleague or parent.	I can match the state goals to our district goals and point out similarities and differences.	I can use these goals to plan my year's units and lessons.	

Using, Constructing and Reflecting Objectives

I am aware that the state core curricular framework is formatted in these areas.	I have successfully used materials that are correlated to these objectives.	I have written units and lessons that reference these objectives at my grade level.	I consistently use these objectives in all unit and lesson planning.	I design units and lessons that integrate the Using, Constructing, and Reflecting Objectives.

Real World Contexts

I believe that science must be connected to real-world contexts in order for students to see its relevance.	I have used units that include real-world contexts for problem solving.	I have developed units that include real-world contexts for problem solving.	I consistently include real-world contexts in my units.	I enlist resource people to meet with students and review their work.

Prerequisite and Subsequent Grade Levels/Courses

I have a sense of what is taught in prerequisite and subsequent grade levels/courses.	I can explain the outcomes expected for mastery in prerequisite and subsequent grade levels/courses.	I use my knowledge of prerequisite and subsequent grade levels/courses in planning.	I regularly discuss student achievement with staff who teach prerequisite and subsequent grade levels/courses.	I plan with staff who teach prerequisite and subsequent grade levels/courses to enhance students' success.

Life Science

I am familiar with the Life Science Objectives	I can perform the tasks inherent in the "Using Life Science" objectives at my grade level.	I use the MDE Life Science Objectives to check instruction throughout the year.	I can perform the tasks inherent in the Constructing and Reflecting Objectives in the context of Life Science.	I use the important questions, the salient metaphors and analogies, and the most significant tasks for the topics I teach.

Physical Science

I am familiar with the Physical Science Objectives.	I can perform the tasks inherent in the "Using Physical Science" objectives at my grade level.	I use the MDE Physical Science Objectives to check instruction throughout the year.	I can perform the tasks inherent in the Constructing and Reflecting Objectives in the context of Physical Science.	I use the important questions, the salient metaphors and analogies, and the most significant tasks for the topics I teach.

CONTENT (continued)

Earth/Space Science

I am familiar with the Earth/Space Science Objectives.	I can perform the tasks inherent in the Using Earth/Space Science objectives at my grade level.	I use the MDE Earth/Space Science Objectives to check instruction throughout the year.	I can perform the tasks inherent in the Constructing and Reflecting Objectives in the context of Earth/Space Science.	I use the important questions, the salient metaphors and analogies, and the most significant tasks for the topics I teach.

ASSESSMENT

Range of Assessments

I use assessment from the textbook to measure students' achievement.	I have experimented with one or more methods of assessing students' understanding.	I develop or use assessments that involve paper/ pencil, performance, and personal communication for every major unit that I teach.	Students create some assessments for their learning.	Students create a portfolio of work to analyze and communicate their work/and achievement.

Appropriateness of Assessments

I use only assessments from the textbook.		I match the level of performance expected with the assessment I use.		I match assessments with challenges students must face, i.e. MEAP/HSPT.

Share in Real World Contexts

I rely on the textbook to make real-world connections.	I ask students to find real-world applications of the knowledge they are learning.	My assessments correspond to real-world situations.	People from our community help evaluate students' work.	Students present their performances or other assessments to an audience.

Students as Partners in Assessment

I discuss each students' achievement with that student.	I communicate to students the standards used to evaluate their work.	Students help me develop standards of quality for projects.		Students discuss, summarize and communicate their evaluation of their work on selected projects.

INSTRUCTION

Inquiry Activities

I use students' questions about nature to begin investigations.	I occasionally engage students in hands-on activities.	I consistently engage students in hands-on activities.	I allow students to design procedures, collect evidence, and draw conclusions.	I engage students in long-term, real life research.

Questioning

I use questions from the textbook for classroom discussion.	I ask questions that challenge students to use evidence and draw conclusions.	I relate all classroom work to significant questions in science.	I design classroom work that balances teacher questions and student questions	I encourage students to ask meaningful questions and articulate their thinking.

Interdisciplinary/Intradisciplinary

I know that science is connected to other disciplines in the real world.	I include at least one other discipline in planning my units in science.	I plan for interdisciplinary and intradisciplinary connections in all units.	I plan units with staff from other disciplines.	I use standards from other disciplines in defining my expectations of students' work.

Cooperative Learning

Students work in groups in labs and projects.	I make the expectations for groups very clear at the beginning of work.	I teach students both the task skills and social skills of group work.	I have students self-assess their task skills and social skills after the group's work is done.	I have scientists discuss with students the need for teamwork and sometimes have them critique students' work.

Diverse Learners

I believe that students come to science with a variety of backgrounds and experiences.	My instruction reflects the contributions to science of people from different ethnicity and races and from both genders.	I assess and consider students' prior knowledge when designing instruction.	I use a variety of teaching techniques to respond to students' learning styles and intelligences.	I allow students to use a variety of methods for solving problems and presenting solutions.

Integrate Technology

I know that technology is important in science and I convey that to students.	I use appropriate technologies to demonstrate scientific techniques.	I integrate all available technologies into my classroom investigations.	I encourage students to determine appropriate technologies for the work to be done.	I use community-based resources to provide students with opportunities for investigating new technologies.

Building Summary

Our Building School Improvement Goal(s) related to Science are the following:

Our building's needs related to Science as determined by the summary of the Staff Needs Assessment:

CONTENT	INSTRUCTION	ASSESSMENT